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CORRECTION.

REVIEW, October, 1923; page 513, May and August diagrams in Figure 4 should be interchanged.

Page 217, in formula (3) the coefficient given as "0.698970" *should be* "0.30103"; likewise, in formula 5 the coefficient *should be* "0.30" instead of "0.70". In the second line below formula (6) the figures "15,259,000,000" *should be* "65,536."

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ALFRED J. HENRY, Editor.

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DAMAGING TEMPERATURES AND ORCHARD HEATING IN THE ROGUE RIVER VALLEY, OREG.

By FLOYD D. YOUNG, Meteorologist, and CLAUDE C. CATE, Plant Pathologist.

[Weather Bureau, Los Angeles, Calif., Oct. 25, 1923.]

INTRODUCTION.

There is a growing tendency on the part of fruit growers and others engaged in agriculture to demand a practical demonstration of the value or correctness of any information or new method connected with their work which varies from their established practice. This is especially true of orchard heating and temperatures which cause damage to fruit blossoms. The tendency at present is away from laboratory experiments and toward the summing up of results observed in actual practice.

The work on which this report is based was begun by the United States Weather Bureau with the primary objects of studying in detail all the different phases of orchard heating and of developing new and more accurate methods of predicting low temperatures. In order to carry on this work it was necessary to obtain very accurate continuous records of the temperature throughout the frosty nights of spring, made with special thermographs, in several different orchards in the Rogue River Valley, in southern Oregon. Since these records were available, it occurred to the writers that they could be used in connection with observations of the amount of damage to fruit following each frost, to give some information regarding the temperatures which cause damage to fruit at different stages of advancement.

Since the pear is the principal fruit crop of the valley, the greater number of observations have been made on this fruit. It appears that comparatively little work has been done to determine temperatures which cause damage to pears; much more information is available regarding critical temperatures for peaches, apples, and apricots.

The latter part of this article is given over to a discussion of the practical value of orchard heating in the Rogue River Valley, and to actual comparisons of the pear crops harvested from adjoining protected and unprotected orchards during the 1921 and 1922 seasons.

DESCRIPTION OF INSTRUMENTS AND EXPOSURES.

It is well known that any object exposed to a clear sky at night will lose heat by radiation to the sky, until its temperature is lower than the temperature of the surrounding air. This is true of a thermometer which is not sheltered from the sky, and is also true of the outer leaves, fruit or blossoms on a tree. For this reason it is often suggested that in determining temperatures which cause damage, an unsheltered thermometer should be used.

There are other matters, however, which must be considered in this connection. Different substances do not radiate heat at the same rate. In general, dark-colored objects radiate heat more rapidly than light-colored objects. Therefore it would not be correct to assume that an exposed alcohol or mercurial thermometer, mounted on a metal back, will indicate correctly the temperature of the green leaves or the white blossoms of the pear tree.

The lower portion of the tree is usually more or less screened from the sky by adjoining trees, and blossoms or fruit in the interior of the tree are almost completely screened by the leaves, branches, and fruit above. The most exposed portion of the tree, and the portion cooled most by radiation to the sky, is the top, and this cooling is nearly always more than offset by the difference in air temperature between the top and bottom of the tree, due to the layer of cold air near the ground.

The object in sheltering a thermometer is to eliminate, so far as possible, the effects of loss of heat by radiation, and to obtain, as nearly as possible, the actual temperature of the air. As a matter of fact, however, the air inside an instrument shelter is usually somewhat colder than that outside the shelter on a clear, calm night, due to the cooling of the shelter itself by radiation to the sky.

It is impracticable to obtain records of the actual temperature of blossoms or fruit on trees in the orchard. The rate of loss of heat by radiation to a clear sky, other factors being the same, depends on the amount of moisture in the air. If the approximate amount of moisture in the air is known, together with other conditions of radiation, an allowance might be made for the cooling of the blossoms or fruit below the air temperature or that registered inside the instrument shelter.

Other sources of error are introduced when an exposed thermometer is used, so that it seems best to use temperatures secured inside a well-ventilated shelter, together with observations of the amount of moisture in the air, in preference to unsheltered thermometer readings, in determining the temperatures which cause damage.

All temperatures shown in this article were secured inside "fruit-region" instrument shelters. (See fig. 1.) These shelters were specially designed for fruit-frost investigational work, by the Instrument Division of the Weather Bureau, to allow a freer circulation of air than in the older designs. Thermometers were 4½ feet above the ground. Thermograph records were usually checked at frequent intervals during the night, so that they are accurate within a few tenths of a degree as a general rule.

Instrument shelters were placed in the center of the intersection of two tree rows. Damage estimates were made from counts of damaged blossoms or fruits from the four trees immediately surrounding the instrument shelter. Positive indication of damage was required before a blossom was counted as injured. Those showing only slight discoloration were counted as uninjured.

From 150 to 350 blossoms were cut open and examined in determining percentages of damage at each count.

DESCRIPTION OF VALLEY.

The portion of the Rogue River Valley in which the studies described in the following pages were made, is about 20 miles long, with an average width of about 6 miles. It is walled in on the south, east, and west by mountains, and narrows down to a gap through which the river flows on the north. The slope of the floor of the valley is from south to north. Freezes, accompanied by strong winds, are practically unknown, although a light wind from a southerly direction is nearly always noted on a frosty night.

Generally speaking, the orchards are exceptionally well cared for, and nearly all the fruit growers attempt to produce high grade fruit. A great many different types of soil are found in the valley. Few growers apply fertilizer of any kind to their trees, although cover crops are grown quite generally. Orchards extend from high up on the hillsides down to some of the lowest ground on the valley floor. Practically none of the orchards on the hillsides are equipped with orchard heaters.

OBSERVATIONS DURING 1919 SEASON.

The weather as a whole during the 1919 season was about normal, and the trees bloomed about the usual time in the spring. Heavy frosts were confined to the colder spots on the low ground; there was no damage by frost to any fruit located on the slopes.

The temperature records shown in Figures 3 and 8 were obtained in two orchards a short distance apart, in one of the coldest spots in the valley. The temperature stations were placed in spots where the records were practically identical when there was no artificial frost protection. One station was located in a pear orchard equipped with 5-quart lard-pail oil heaters and the other was in an adjoining pear and apple orchard not equipped with heaters. The age of the trees in the fired orchard was 19 years; and at the check station the ages were: Winter Nelis 25 years, Howell, Bartlett and Anjou, 15 years, Newtown apples 20 years. The soil at both stations was clay adobe, and the orchard care was excellent. The following specific comments may be made with reference to the several diagrams:

Figure 3—Damage to blossoms.—Evening dew point 33° F. Check station (unprotected): Newtown apple buds not yet showing pink; Winter Nelis pear buds showing pink; no damage to either by frost. Fired orchard: Bartlett, Clairgeau, and Anjou approaching full bloom. No damage.

Figure 4—Damage to blossoms.—Evening dew point 30° F. Check station (unprotected): Newtown apple buds not yet showing pink; Winter Nelis pear buds showing pink. No damage to either by frost. Fired orchard: Anjou and Howell pear trees in bloom; Bosc, Winter Nelis and Comice buds showing pink. No damage to any variety near station on this night. No damage could be found in the entire valley following this frost, even where no orchard heating was done. Banks of clouds gathered on the eastern horizon just before sunrise, and direct sunlight did not strike trees until two or three hours later.

Figure 5—Damage to blossoms.—Evening dew point 27°. Anjou, Bartlett and Howell pear trees in full bloom; Bosc within two days of full bloom; Nelis and Comice about four days before full bloom. Newtown apple buds showing pink. Check station (unprotected): Newtown apple buds not damaged. Winter Nelis pear buds not damaged. Anjou and Howell pear blossoms show 25 per cent damage. Fired orchard: No damage to Howell, Anjou, Clairgeau, Bartlett, Bosc, Comice, or Winter Nelis pear blossoms or buds. No clouds in sky after sunrise.

Figure 6—Damage to buds and blossoms.—Evening dew point 32°. Bartlett, Howell, Anjou pear trees in full bloom; Clairgeau pear trees within two days before full bloom; Winter Nelis within three days of full bloom; Bosc and Comice about four days before full bloom. Newtown apple buds in late pink stage. Check station (unprotected): Newtown apple buds show 4 per cent damage. No evidence of any damage found in Winter Nelis pear buds. Bartlett blossoms show 52 per cent injury, mostly in earlier bloom. Howell pear blossoms show 67 per cent injury. Fired orchard: No damage to Howell, Anjou, Clairgeau, or Bartlett blossoms, or to Bosc, Comice or Winter Nelis buds.

Figure 7—Damage to fruit.—Evening dew point 35° Photographs (figs. 10 and 11) show stage of development of different varieties of pears, and of Newtown apples. It was not possible to check on the amount of damage on the following day, and as another frost occurred on the night of May 4–5, the damage on these two nights was checked together. See Figure 8 for damage estimates.

Figure 8—Damage to fruit.—Evening dew point 31°. Photographs (figs. 10 and 11) show stage of advancement of Newtown apples and different varieties of pears. Following records of damage include damage done on previous night. (See fig. 7). Check station (unprotected): Newtown apples in lower half of trees show 85 per cent badly discolored, and a small proportion of the remaining 15 per cent slightly discolored. Nearly all of the larger fruits badly discolored; uninjured fruits practically all small. In upper half of trees, where the average lowest temperature for 45 minutes was 29.8°, from 45 to 50 per cent of the fruits showed discoloration. Winter Nelis pears in lower half of trees showed 65 per cent badly discolored and 30 per cent slightly discolored. In upper half of trees from 35 to 40 per cent of the fruits were discolored. All of this damage was done on the nights of May 3–4 and 4–5, as blossoms damaged in previous frosts had fallen from the trees some time previously. Fired orchard: No damage to Howells, Anjou, Clairgeau, Bartlett, Bosc, Comice, or Winter Nelis pears in immediate vicinity of temperature station. In portion of orchard fired last, Bartlett pears had already begun to blister badly, indicating that critical temperature had been reached.

It will be noted that on the night of April 13–14, (fig. 6) Winter Nelis pear buds, within two days of full bloom, withstood a temperature of 26° F. or below for one hour, with a minimum temperature of 25° F., without injury.

Six days later, on the night of April 19–20, when the trees were slightly past full bloom but the petals had not been shed, a temperature of 30° F. for 30 minutes caused about 17 per cent damage. This variety of pear tree practically always carries a heavy bloom, and so small a loss would have no effect on the final crop.

On the night of May 4–5, (fig. 8) when the petals had been shed and the fruits were about one-fourth inch in diameter, a temperature of 27° F. for about one hour caused 65 per cent of the fruit on the lower half of the trees to show deep discoloration and about 30 per cent more showed slight discoloration. Near the tops of the trees, where the average lowest temperature for 45

(To face p. 618.)

FIG. 1.—Fruit region instrument shelter in which temperature records were obtained.

FIG. 2.—Pear orchard equipped with 250 2-gallon lard-pail oil heaters to the acre.

FIG. 9.—Stage of development of pears, blossoms, and fruits on April 21, 1919. Left, Comice; right, Winter Nelis; upper, Bartlett; lower, Anjou.

FIG. 10.—Stage of development of pears on May 4, 1919. Upper left, Anjou; lower left, Comice; upper right, Winter Nelis; lower right, Bartlett.

FIG. 11.—Stage of development of fruit on May 5, 1919. Lower right and left, Newtown apples; upper right and left, Winter Nelis pears.

(To face p. 619.)

FIG. 17.—Stage of advancement of Bartlett and Bosc pears on May 3, 1921.

FIG. 30.—One of the many acres of Comice pear trees which carried a heavy crop of fruit near their tops, with very little fruit in the lower portions, in 1921, due to stratification of the air on frosty nights.

FIG. 31.—Comice pear trees shown in Figure 30, showing distribution of crop in 1922 when the orchard was protected with orchard heaters.

FIG. 32.—Stage of development of pear buds on April 17, 1922. Left to right, Anjou, Bartlett, Anjou. Two clusters of each are shown representative of the greatest—and least—developed blossoms.

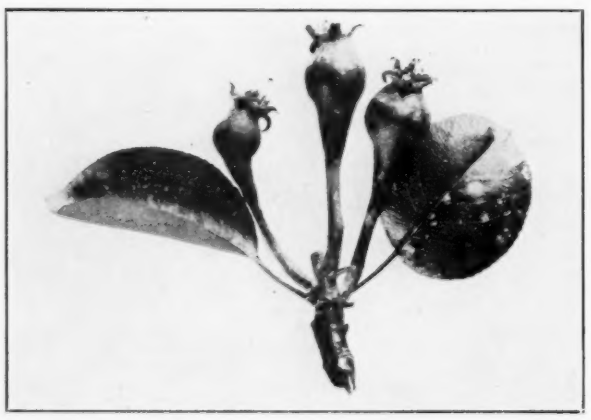

FIG. 34.—Stage of Bartlett pears on May 27, 1922. Several acres of fruits in this stage were frozen almost to the core on the morning of May 27. Practically all of them recovered completely, without marking or other indication of injury.

FIG. 33.—Stage of development of pears on April 20, 1922. Left to right: Anjou, Bo[illegible] Bartlett.

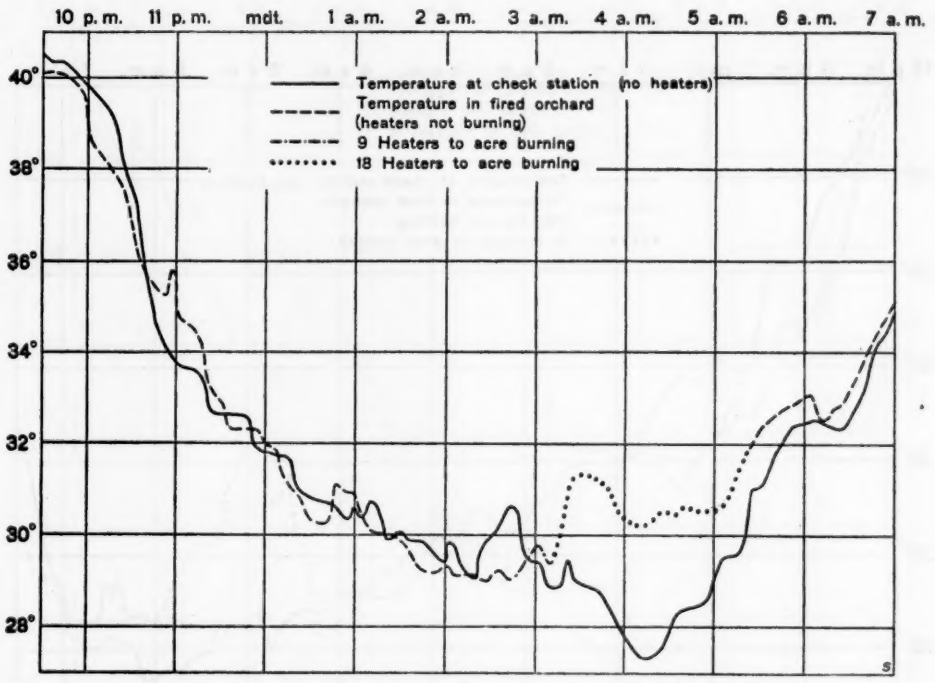

FIG. 3.—Temperature records in fired orchard and at outside check station on night of April 6–7, 1919. Temperature raised 2½° F. by using 18 heaters to the acre.

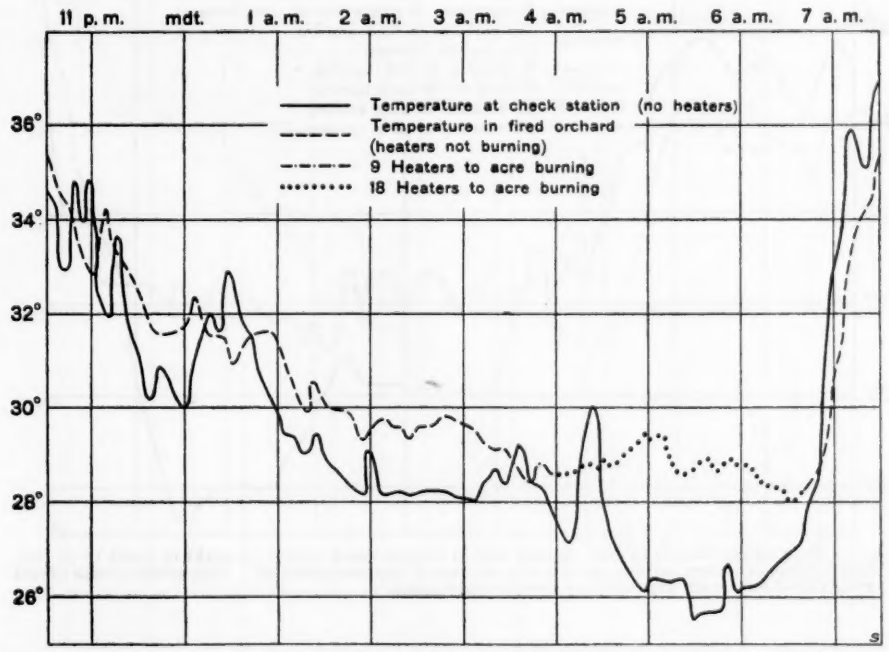

FIG. 4.—Temperature records in fired orchard and at outside check station on night of April 7–8, 1919. Results of firing about the same as on previous night shown in figure 3.

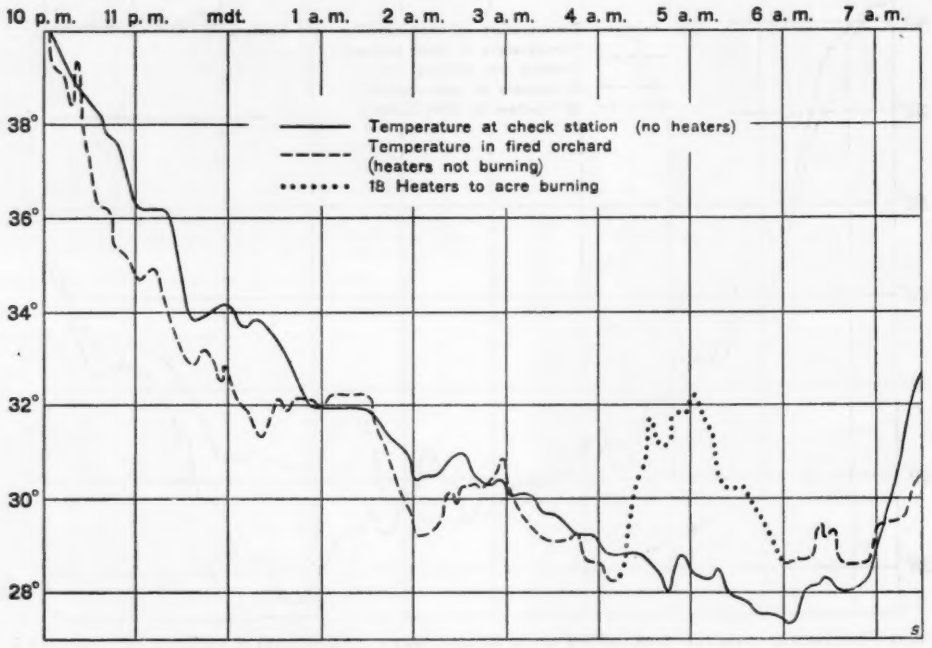

FIG. 5.—Temperature records in fired orchard and at outside check station on night of April 10–11, 1919. Heaters burning very low and beginning to go out after 5 a. m.

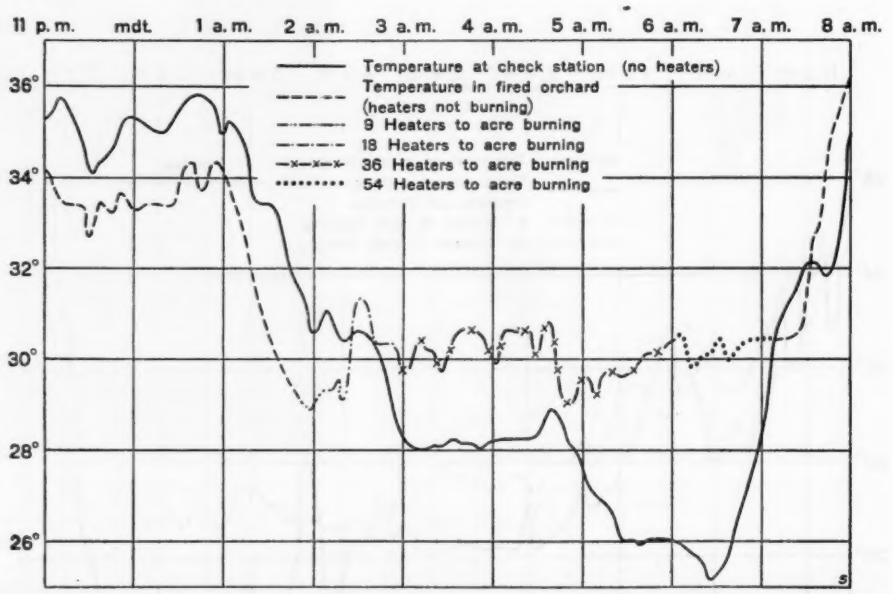

FIG. 6.—Temperature records in fired orchard and at outside check station on night of April 13–14, 1919. First lighting of heaters burning out at 4.40 a. m., caused temperature to fall. Temperature inside heated orchard held five or six degrees above outside temperature.

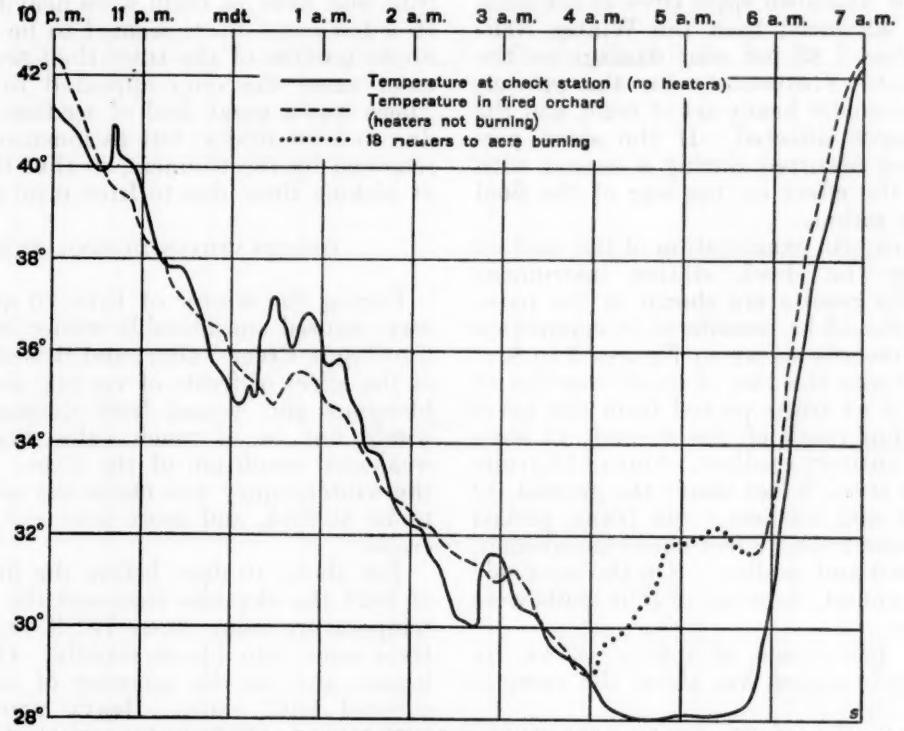

FIG. 7.—Temperature records in fired orchard and at outside check station on night of May 3–4, 1919. Temperature was raised about 4° F. by using 18 heaters to the acre.

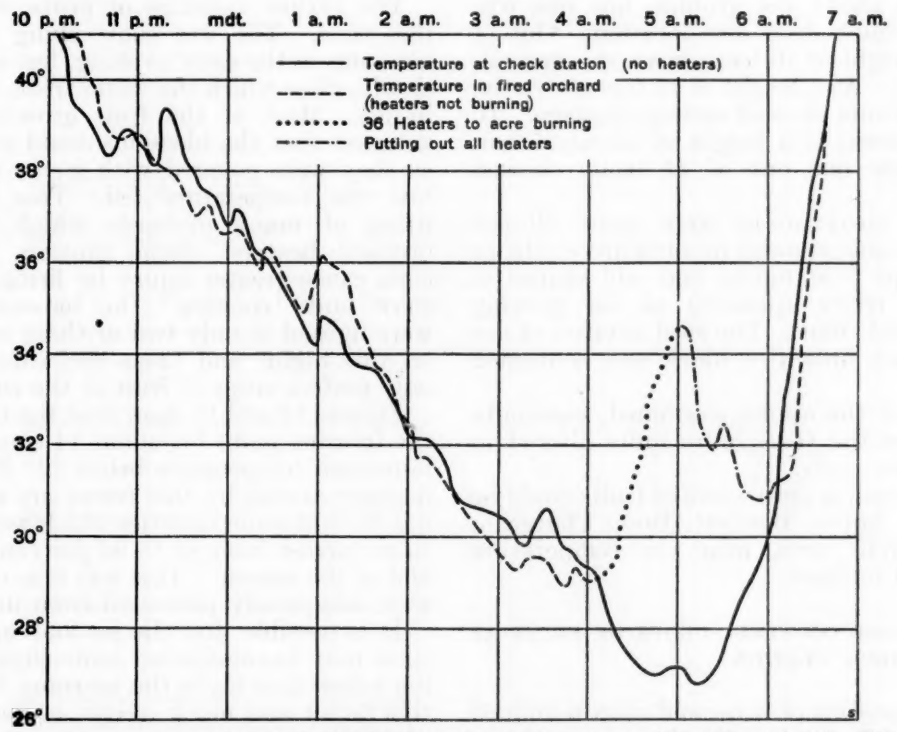

FIG. 8.—Temperature records in fired orchard and at outside check station on night of May 4–5, 1919. This was the most remarkable rise in temperature ever observed in the orchard-heating investigations of the Weather Bureau. Temperature rose 7½° F. with 36 heaters to the acre burning. Weather conditions were almost idea lfor this work. Compare with figure 6.

minutes was 29.8°, the damage amounted to from 35 to 40 per cent.

Small fruits or Yellow Newtown apple trees at the same location, slightly less advanced than the Winter Nelis fruits on this date, showed 85 per cent damage on the day following the frost. Fortunately for the grower, the trees had an exceptionally heavy set of fruit, and the final crop was not much affected. If the same percentage of damage had occurred during a season with light setting of fruit, the effect on the size of the final crop would have been serious.

On May 10, 1919, a careful examination of the fruit on the trees surrounding the check station instrument shelter was made. The results are shown in the paragraphs below. They should be considered in connection with the temperature records shown in Figures 3 to 8.

Howell pears.—All fruits the size of small marbles or slightly larger. Out of 44 fruits picked from the lower part of the trees, within reach of the ground, 42 were badly discolored and entirely seedless. Out of 14 fruits on the east side of the trees, 8 feet above the ground, 12 were badly discolored and seedless. Six fruits picked from east side of the same trees, 10 feet above the ground, were all badly discolored and seedless. On the west side of the trees, near the ground, three out of four fruits were discolored and seedless.

Anjou pears.—The percentage of injury shown by Anjou pears at the check station was about the same as shown by the Howell.

Winter Nelis pears.—Out of 38 fruits nearest the ground, 30 were discolored. Out of 15 fruits picked at a height of 7 feet above the ground, 10 were discolored. At a height of 10 feet above the ground, only 3 out of 12 pears showed discoloration.

Yellow Newtown apples.—Out of 63 fruits picked within a height of 8 feet above the ground, not one was found which did not show deep discoloration. Out of 15 fruits picked at a height of 10 feet above the ground, 9 showed discoloration. At a height of 12 feet above the ground, 18 out of 25 fruits showed serious damage. In the very tops of the trees, at a height of about 25 feet above the ground, only one out of 11 fruits showed injury.

At the time these observations were made all the varieties of pears examined showed no outward evidence of frost damage, except frost marks and odd shapes in the Anjou. All the fruits appeared to be growing rapidly and were of good color. The seed cavities of the injured fruits were dark brown or black and contained no seeds.

A large proportion of the apples examined, especially in the lower portion of the trees, were quite altered in shape, and contained no seeds.

No damaged, misshaped, or frost-marked fruits could be found at this time in Anjou, Bartlett, Bosc, Clairgeau, Comice, or Winter Nelis trees near the temperature station inside the fired orchard.

EFFECT OF FROST DAMAGE ON FINAL CROPS OF FRUIT AT CHECK STATION.

Howell.—About 5 per cent of a normal crop remained on the trees at picking time and about 90 per cent of this fruit was seedless.

Anjou.—About 15 per cent of a normal crop remained on the trees at picking time.

Winter Nelis.—About 60 per cent of a full crop was harvested.

Yellow Newtown apples.—At the end of the season the Yellow Newtown apple trees nearly all bore a full crop of fruit and most of them were heavily thinned artificially. In a few cases there seemed to be a heavier crop in the upper portion of the trees than near the ground, but in most cases the crop appeared to be well distributed. There was a great deal of seedless and misshapen fruit, due to frost injury, but as much of this as possible was removed by the thinners, so that the percentage of culls at picking time, due to frost injury, was not large.

OBSERVATIONS DURING THE 1921 SEASON.

During the winter of 1919–20 an unprecedented cold wave caused considerable winter injury to fruit trees in the Rogue River Valley, and it was thought observations of the effect of frosts of varying degree in damaging the blossoms and young fruit during the spring of 1920 would not be of much value because of the possible weakened condition of the trees. As a matter of fact, the winter injury was much less severe than it appeared to be at first, and most pear and apple trees bore full crops.

For about 10 days before the first frost in the spring of 1921 the sky was clear and the afternoons warm, the temperature rising above 70° F. on several dates. Fruit trees came into bloom rapidly. On April 2 a cold rain began, and on the morning of the 3d, the hills were covered with snow. Heavy snow squalls alternated with periods of clear sky and bright sunshine during the day, until about 4 p. m., when a heavy snow squall set in, lasting until nearly 7 p. m. Another snow squall passed over about 8:30 p. m. The sky cleared completely before midnight, and remained clear during the remainder of the night.

The earlier varieties of pears were in full bloom at this time. The wet snow clung to the branches and blossoms in the early evening, but later most of it melted slowly, after which the water froze, encasing the blossoms in ice. Most of the fruit growers labored under the delusion that the blossoms could not be injured, so long as they were covered with ice or snow, no matter how low the temperature fell. This belief prevented the firing of many orchards which were equipped with orchard heaters. Some growers believed they might even cause greater injury by firing, through melting the snow and "cooking" the blossoms. Orchard heaters were lighted in only two or three orchards in the district on this night, and these orchards harvested about the only perfect crops of fruit at the end of the season.

Figures 12 and 18 show that the temperature was below the freezing point for about 14 consecutive hours, with a minimum temperature below 22° F. The records of the damage caused by this freeze are exceptionally interesting, in that some varieties which were in full bloom at this time carried from 85 to 90 per cent of a full crop at the end of the season. This was true only of orchards which were adequately protected from damage by later frosts.

It is possible that the ice and snow covering the blossoms may have afforded some slight protection, by causing a slow thawing in the morning, but it is not likely that this factor had much weight in determining the amount of damage.

The temperature records shown in Figures 12 to 16 were secured at the same locations as the records shown in Figures 3 to 8. The orchard in which one of the stations was located contained 150 five-quart lard-pail oil orchard heaters to the acre. The check station was

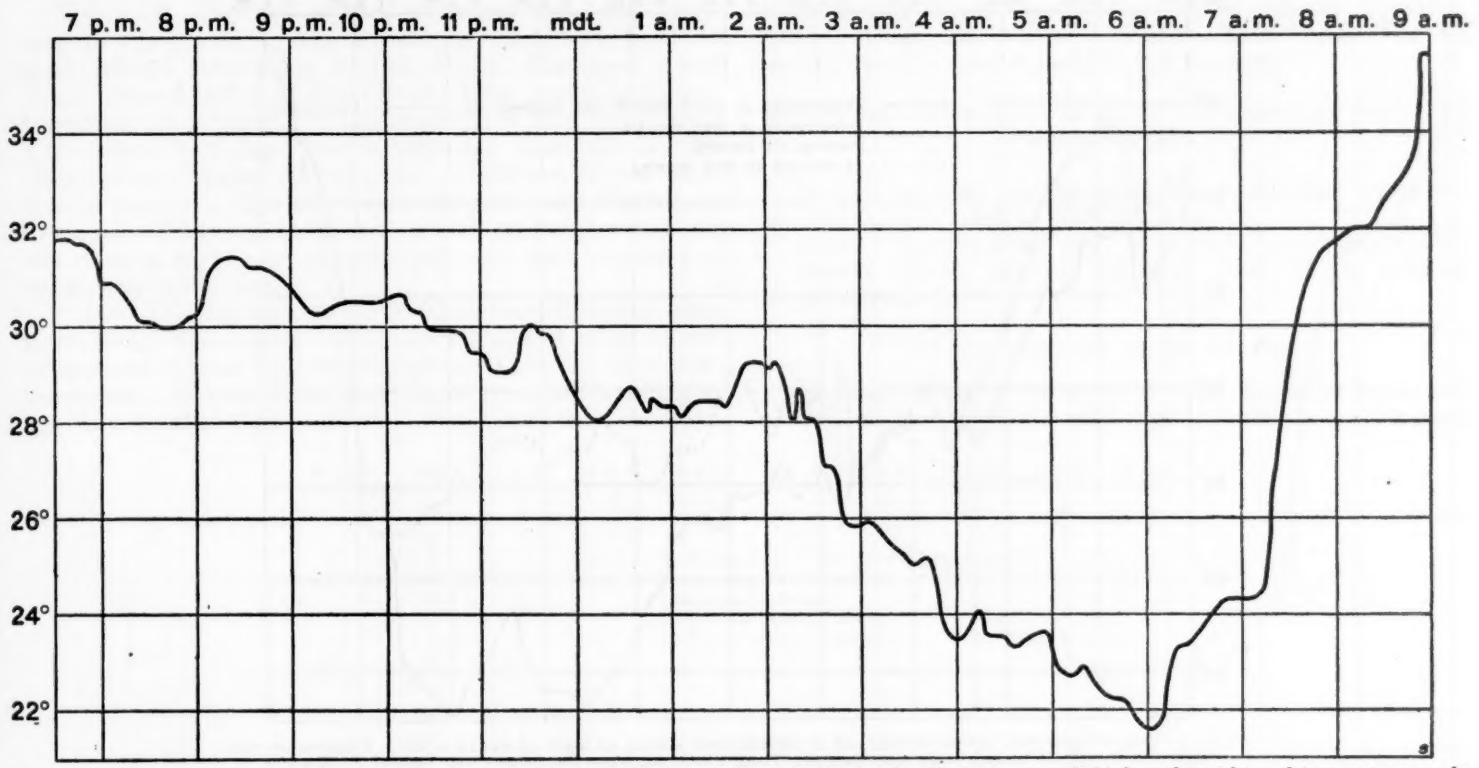

FIG. 12.—Temperature record at check station unprotected (adjoining orchard) on night of April 3-4, 1921. No heaters were lighted on this night, and temperature records at the two places were practically identical.

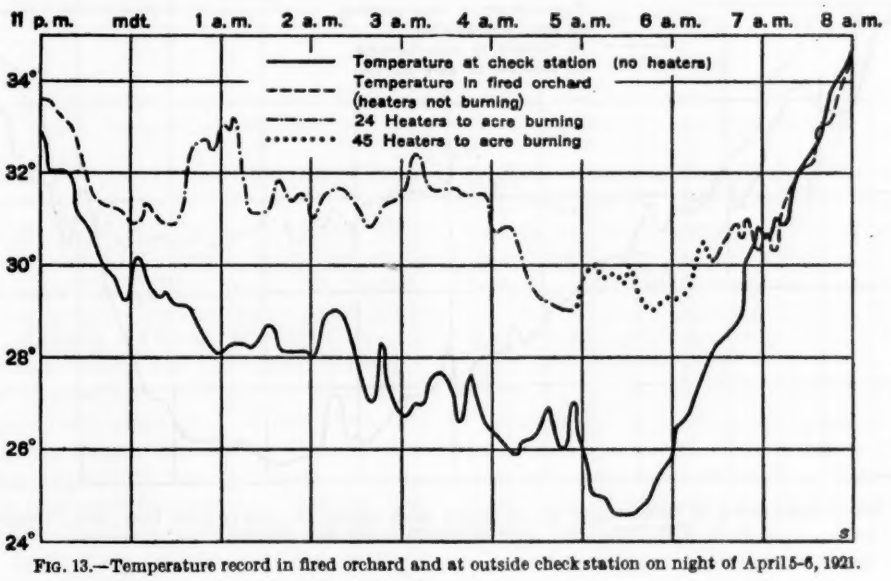

FIG. 13.—Temperature record in fired orchard and at outside check station on night of April 5-6, 1921.

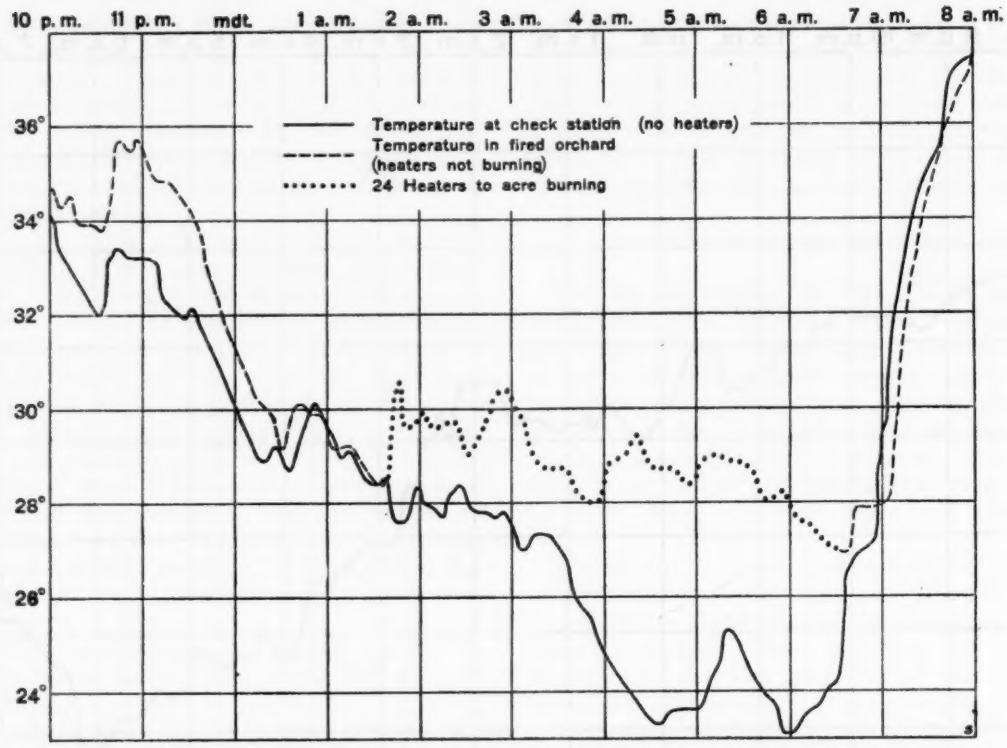

FIG. 14.—Temperature record in fired orchard and at outside check station on night of April 6-7, 1921. Temperature rose from 4 to 5° with 24 heaters to the acre burning. From 1.30 a. m,, when the heaters were lighted, until 3.45 a. m. no heaters were burning within 150 feet of the station on the east and within 250 feet on the west. No heaters were lighted north of the station and none within 300 feet of the station on the south. At 3.45 a. m. a few scattering heaters were lighted in this area.

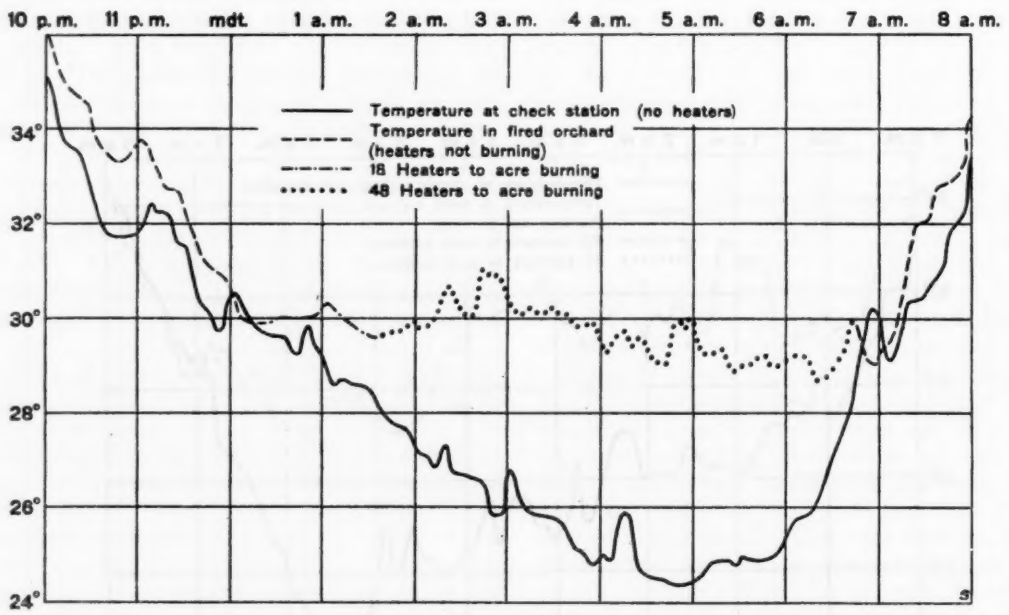

FIG. 15.—Temperature record in fired orchard and at outside check station on night of April 13-14, 1921. Temperature rose from 4 to 5° with 48 heaters to the acre burning.

located in an adjoining orchard, which contained no heaters. The effects of the firing of the heaters on different nights is shown in the diagrams.

Figure 12—Damage to fruit buds and blossoms.—Evening dew point 32°. Anjou pears in full bloom; Bartlett pears about two-thirds in full bloom; Clairgeau pears about three-fourths in full bloom; Bosc pears buds just beginning to separate in the cluster; Winter Nelis pear buds about four days before opening. Bartlett damage 50 per cent. Anjou 82 per cent. Clairgeau 60 per cent. Bosc 4 per cent, Winter Nelis 2 per cent, and Comice no damage. Trees and blossoms were covered with water and wet snow in early part of the night, and were encased in ice during latter part.

Figure 13—Damage to pear blossoms.—Evening dew point 29°. See Figure 14 for description of stage of development of pear buds and blossoms. Check station (unprotected): Winter Nelis buds show no additional damage due to this night's frost. Fired orchard: Bartlett, Clairgeau, Bosc, Winter Nelis and Comice blossoms show no additional damage.

Figure 14—Damage to pear blossoms.—Evening dew point 27°. Anjou pears past full bloom; Bartlett pears in full bloom; Clairgeau pears slightly past full bloom; Bosc pear buds showing pink; Winter Nelis pear buds about two days before opening. Check station (unprotected): Howell blossoms show 86 per cent damage, including damage done on previous cold nights of season. Winter Nelis show 6 per cent damage. Fired orchard: Bartlett, Anjou, Clairgeau, Bosc, Winter Nelis and Comice pear blossoms show no additional damage.

Figure 15—Damage to buds and blossoms.—Evening dew point 33°. There was considerable cloudiness during the forenoon of the 14th, beginning before sunrise, causing frozen fruit and blossoms to thaw slowly. Practically no damage could be noted on the 14th due to this frost. Damage done on this night is included with that shown in the frost on the following night. (See fig. 16.)

Figure 16—Damage to pear buds and blossoms.—Evening dew point 33°. Winter Nelis, Bosc and Comice pears in full bloom. Howell, Bartlett, Anjou and Clairgeau blossoms had shed most of their petals at this time. Check station (unprotected): Winter Nelis show 59 per cent injury. Anjou show 55 per cent injury. Howell show 72 per cent injury.[1] Fired orchard; Bartlett, Anjou, Clairgeau, Bosc, Winter Nelis and Comice pear blossoms show no additional damage.

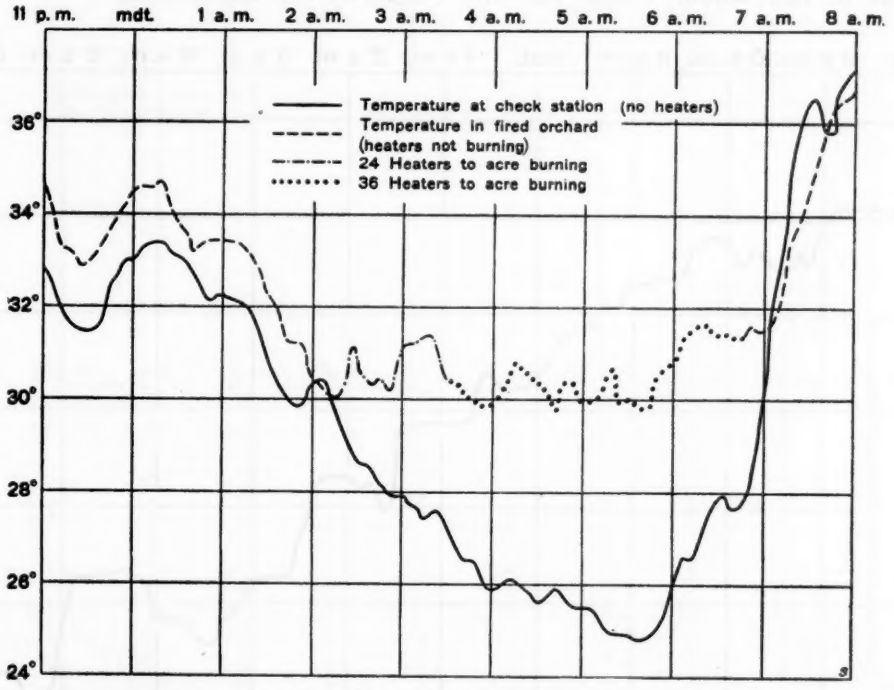

FIG. 16.—Temperature record in fired orchard and at outside check station on night of April 14–15, 1921.

EFFECT OF FROST DAMAGE ON FINAL CROPS OF FRUIT AT CHECK STATION.

Howell.—About 1 per cent of a normal crop remained on the trees at picking time.

Anjou.—About 3 per cent of a normal crop harvested.

Winter Nelis.—About 10 per cent of a normal crop harvested.

FINAL CROPS AT FIRED ORCHARD.

The damage to the crop in the fired orchard was caused almost entirely on one cold night, April 3–4. On succeeding frosty nights during the season the temperature was maintained well above the danger point through the use of orchard heaters. The percentages of full crops (estimated) for each variety in this orchard are given below. The light crop of Comice pears was not due entirely to frost damage, but at least the greater part of the reduction of the crop of other varieties of pears was probably due to frost.

Howell.—Seventy per cent of a normal crop harvested.

Anjou.—Fifty-five per cent of a normal crop was harvested. About 1 per cent of this fruit was frost marked, but not seriously. Ninety-five per cent of the fruit was on the outside of the tree, due to the fact that late bloom is found there.

Winter Nelis.—Ninety-five per cent of a full crop harvested.

Bartlett.—Eighty-five per cent of a full crop harvested, mostly on the outside of the trees. About 1 per cent were slightly frost marked.

[1] These percentages are of blossoms remaining on the trees. Blossoms injured in previous frosts have all dropped to the ground. See percentage of full crop at end of season.

Clairgeau.—Ninety per cent of a full crop harvested, mostly on the outside of the trees. About 1 per cent slightly frost marked.

Bosc.—Seventy per cent of a full crop harvested.

Comice.—Five per cent of a full crop harvested. This variety has always been a light bearer in this orchard. The light crop was probably not due to frost injury.

DAMAGE AT SECOND LOCATION.

During the 1921 frost season a temperature station was maintained in a cold spot about 5 miles distant from the locations of the stations shown in Figures 12 to 16. The records from this station, together with estimates of the amount of damage caused on each cold night, are shown in Figures 18 to 21. This orchard was not equipped with orchard heaters.

Figure 18—Damage to fruit buds and blossoms.—Evening dew point 32°. Anjou pears in full bloom; Bartlett pears about two-thirds in full bloom; Clapp Favorite pears in full bloom; Bosc pear buds just beginning to separate in the cluster; Winter Nelis pear buds about four days before opening. Bartlett damaged 90 per cent, Anjou 78 per cent, Bosc 20 per cent, Winter Nelis 31 per cent, and Clapp Favorite 80 per cent. Compare with damage to same varieties in Figure 14. Trees and blossoms were covered with water and wet snow in early part of the night, and were encased in ice during the latter part. All trees about 15 years old.

Figure 19—Damage to buds and blossoms.—Evening dew point 29°. Bartlett show 92 per cent damage, Anjou 88 per cent, Bosc 98 per cent, Winter Nelis 44 per cent, and Clapp Favorite 90 per cent. These percentages include damage done on previous night. Damage due to night of April 5–6: Bartlett 2 per cent, Anjou 10 per cent, Bosc 78 per cent, Winter Nelis 13 per cent, and Clapp Favorite 10 per cent. Note that about 95 per cent of the Bosc and Winter Nelis blossoms were not open at this time.

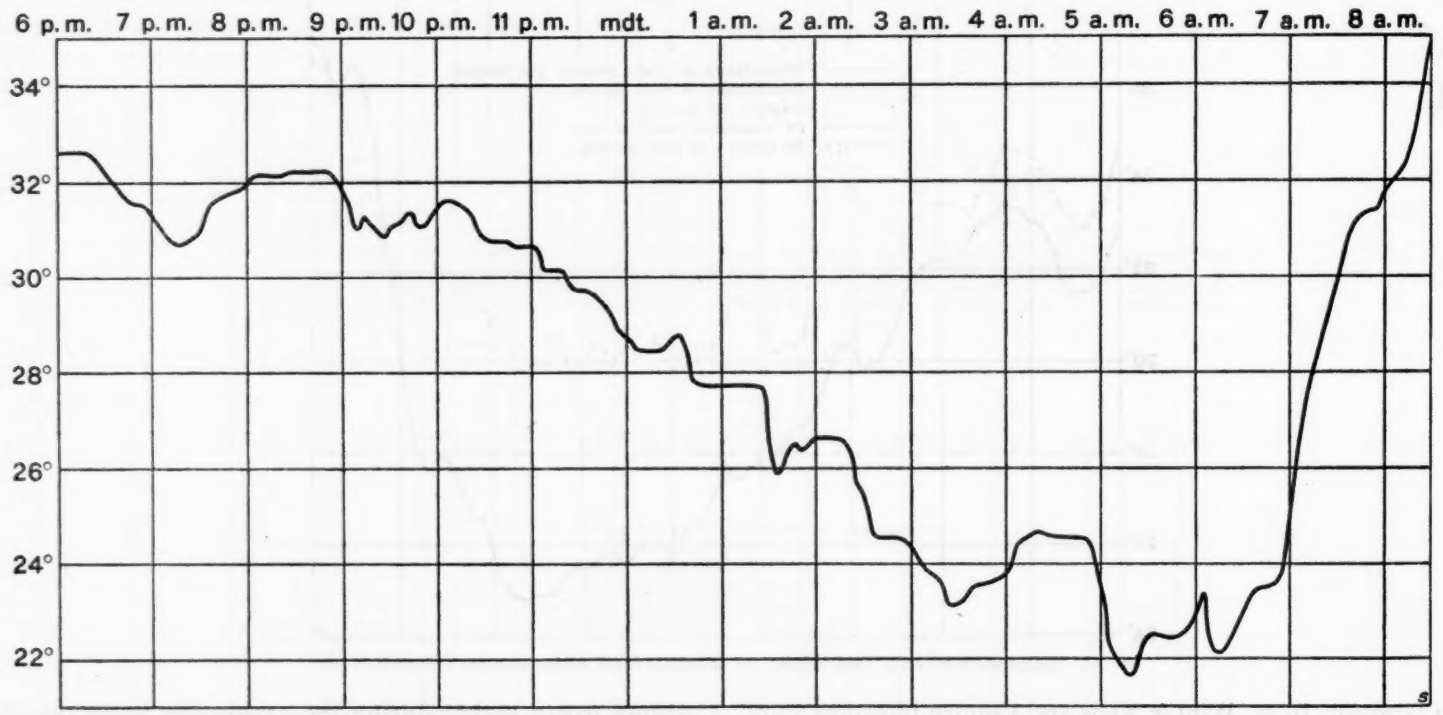

FIG. 18.—Temperature record in an orchard not equipped with orchard heaters, April 3–4, 1921.

Figure 20—Damage to buds and blossoms.—Evening dew point 27°. No additional damage was found following this frost. Practically all the more advanced blossoms had been badly damaged or killed on the previous night, leaving only the latest bloom showing clear. This late bloom, as a rule, was not damaged by the frost on the night of the 6th–7th.

Figure 21—Damage to blossoms and fruit.—Evening dew point 33°. Winter Nelis, Bosc, and Comice pears in full bloom. Howell, Bartlett, Anjou, and Clapp Favorite blossoms had shed most of their petals at this time. Winter Nelis show 42 per cent injury, Anjou 60 per cent, Bosc 99 per cent, Bartlett 81 per cent, and Clapp Favorite 83 per cent injury. In the case of all these varieties except Bosc, the fruit had formed at this time, and all blossoms damaged in previous frosts had dropped from the trees. These percentage estimates cover fruit that had escaped injury in former frosts. In some cases there was practically no fruit left on the trees to be damaged by this latest frost.

Probably the most interesting feature in connection with these records is the killing of practically all the blossoms on Bosc trees before they had opened, by temperatures of 22° F. and 23° F. Winter Nelis blossoms also were killed, to a lesser extent, in these two frosts.

EFFECT OF FROST DAMAGE ON FINAL CROP.

Anjou.—Three per cent of a normal crop harvested.

Winter Nelis.—Five per cent of a normal crop harvested.

Bartlett.—Fifty per cent of a normal crop harvested. practically all badly frost marked and misshapen.

Bosc.—Two per cent of a normal crop harvested.

Clapp favorite.—Fifty-five per cent of a normal crop harvested. Most of crop in upper half of tree. Nearly all seedless and misshapen. Seedless pears still falling to the ground at picking time. Ground covered with nearly mature fruit.

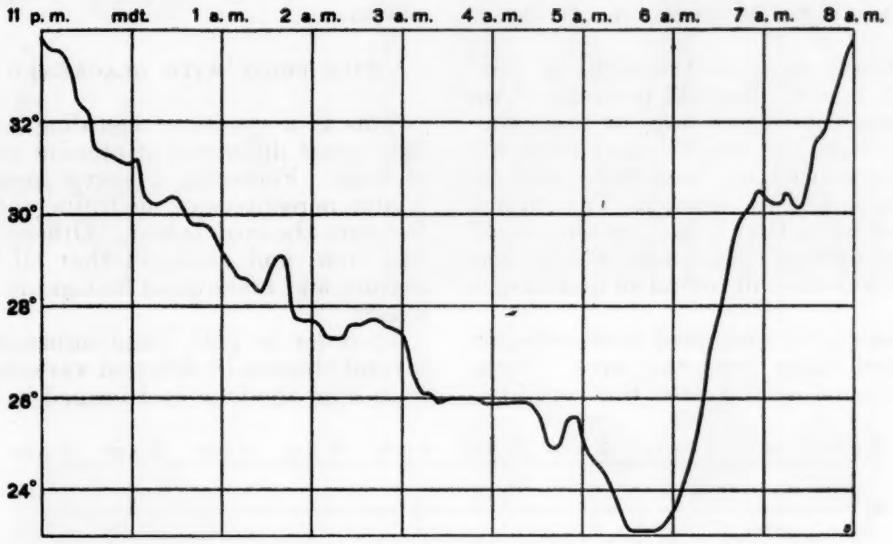

FIG. 19.—Temperature record in an orchard not equipped with orchard heaters, April 5-6, 1921.

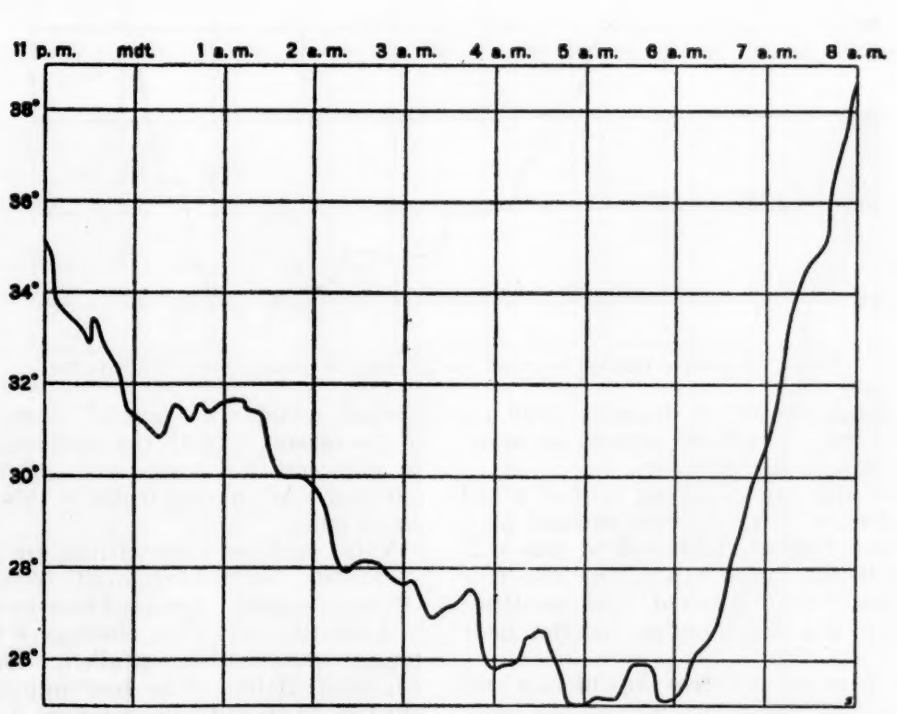

FIG. 20.—Temperature record in an orchard not equipped with orchard heaters, April 6-7, 1921.

A particularly close study was made of a Clapp Favorite tree at station 2, following the first cold night, which caused 80 per cent of the blossoms to show deep discoloration. This tree was about 15 years old and from outward appearances in a vigorous condition. It carried a heavy bloom.

Following the last heavy frost on the night of April 14–15, a careful count showed about 83 per cent of the fruits, which were about the size of peas at that time, were badly discolored. If all the fruit on the tree at this time had matured there would have been more than the tree could carry at the end of the season. The injured fruits were so badly discolored that it was possible to tell by inspection, without cutting the fruits, which were injured. At this time it was difficult to find an undamaged fruit on the tree.

On May 6 this tree was again examined to see whether the discolored fruits had fallen from the trees. There was some fruit on the ground on this date, but very little in comparison to the total amount of damaged fruit on the tree. None of the fruit, however, injured or uninjured, seemed to be making much growth.

On August 9 this tree still carried 55 per cent of a full crop. The ground underneath the tree was covered with large, seedless, misshapen fruits, and the drop was still continuing. The fruit in the lower half of the tree was practically 100 per cent frost marked and seedless. (See fig. 38.) The crop was considerably heavier near the top.

On September 2 the fruit on this tree was picked and measured in field boxes and graded entirely on the basis of shape. There were four boxes of badly misshapen and seedless fruit and one box of fruit of normal shape on the tree, and one and one-fourth boxes of mature fruit was on the ground under the tree. A great many of the pears in the box of normal shaped fruit were frost marked.

These observations are especially interesting in showing that even though this variety of pear may be so severely injured by frost that the seeds are killed, a considerable portion of the crop may remain on the trees until maturity, although the fruit is likely to grade very low. Another interesting point is the fact that about one-sixth of a normal crop of fairly good fruit was matured, although temperatures of 21.5° F. and 23° F. were recorded during the period when the tree was in full bloom.

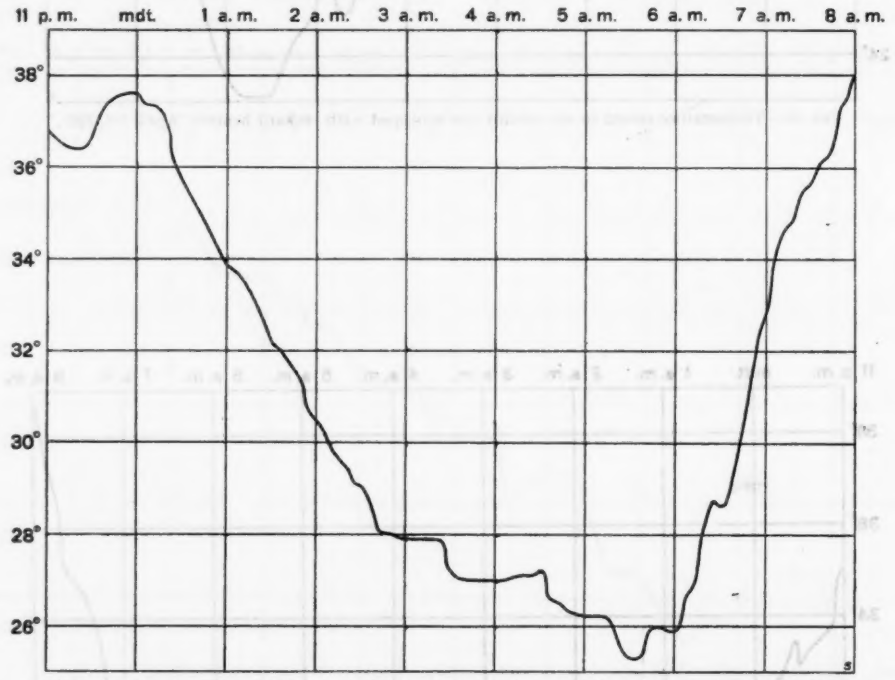

FIG. 21.—Temperature record in an orchard not equipped with orchard heaters, April 14–15, 1921.

WILL FRUIT WITH BLACKENED CENTERS MATURE?

This is a question regarding which there has always been great difference of opinion among practical growers of fruit. Following a heavy frost which has discolored a large percentage of the fruits on the trees, some growers feel sure the crop is lost. Others take exactly the opposite view, and maintain that all the injured fruits will mature and make good first-grade fruit at the end of the season.

In order to gain some information on this question, several clusters of different varieties of pears were tagged soon after the fruit had formed in the spring of 1921 and a close watch was kept of them during the remainder of the season. In all the clusters marked, it was possible to pick out the fruits with discolored centers without cutting. All injured fruits of this kind showed darkened calyx ends.

Notes on these observations are given below.

Bartlett fruits.—Irrigated trees, 9 years old. Soil, Olympic adobe. Orchard care excellent.

April 12, 1921: Four clusters of five Bartlett pears each tagged; petals all have fallen. Every fruit shows injury without cutting. The best appearing fruit in a similar cluster, when cut, showed deep discoloration. All fruits are growing well, and from outward appearances are vigorous and healthy.

April 20, 1921: All clusters except one are showing a sickly yellow and appear about ready to drop.

May 9, 1921: Only three pears left, all in one terminal cluster. Two of these are badly frost-marked (ring-necked).

June 9, 1921: All pears in tagged clusters have fallen to the ground.

August 9, 1921: About 14 pears remain on entire tree, mostly near the top.

(To face p. 628.)

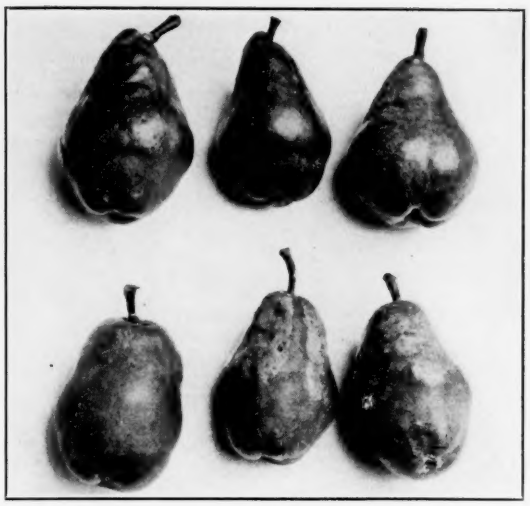

FIG. 35.—Mature Bartlett pears, showing woody russet markings on the frost-injured fruit.

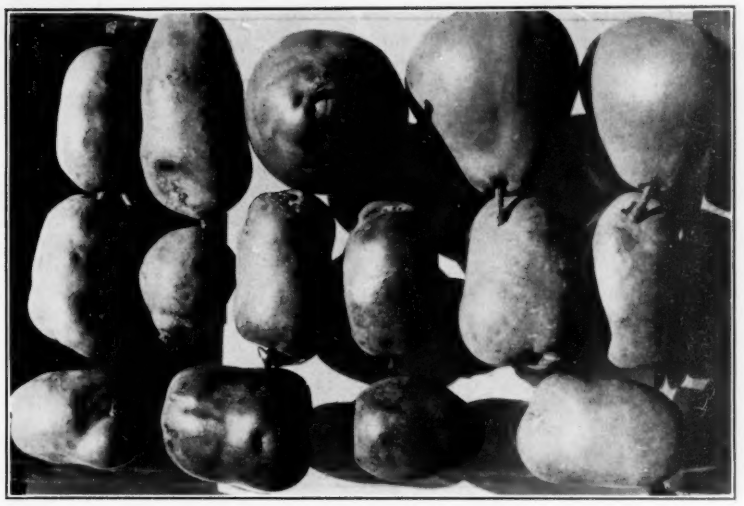

FIG. 37.—Clapp Favorite pears in which the seeds have been killed by frost. The three pears in upper right-hand corner are of normal size and shape.

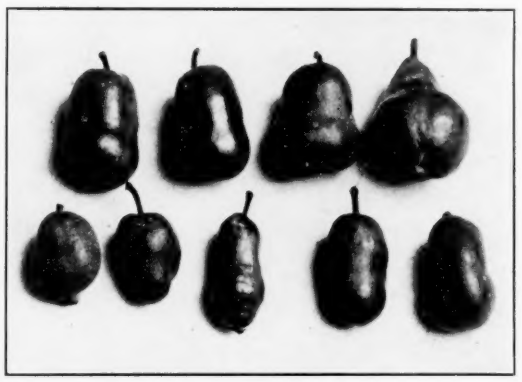

FIG. 36.—Odd shapes assumed by Bartlett pears in which the seeds have been killed by frost. The pear in the upper right-hand corner is of normal shape and size.

FIG. 38.—Cross sections of young pears, showing effect of frost. Two fruits in lower left-hand corner are normal; others are seedless and discolored.

FIG. 39.—Howell pears from an orchard protected with heaters, after the heavy frosts of 1921. A heavy crop was set and the fruits grew rapidly. Compare with a topical branch of Howell pears from tree in unprotected orchard, shown in Figure 40.

FIG. 40.—Typical branch from Howell pear tree in unprotected orchard near that from which the branch shown in Figure 39 was obtained. All blossoms were stunted and yellow, and fell rapidly. A large proportion of the blossoms fell from the branch while it was being brought in to be photographed. A condition of this kind is very often attributed by the grower to "lack of pollination."

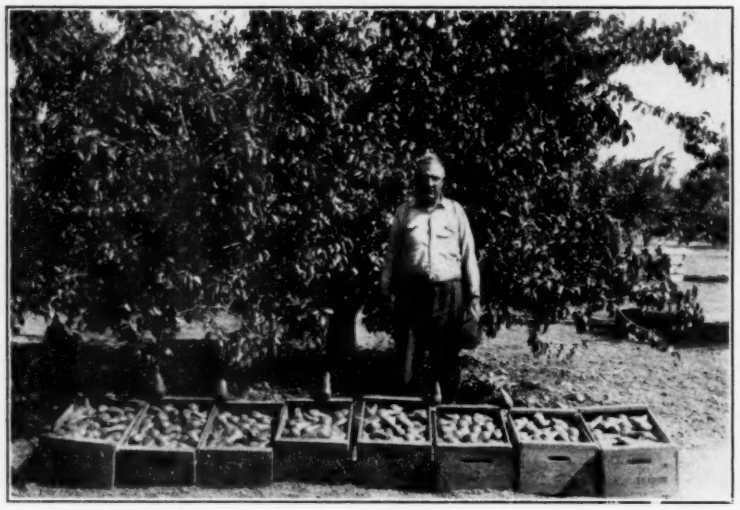

FIG. 41.—Average size of crop per tree of Bosc pears harvested in orchard protected with lard-pail orchard heaters during the severe frost season of 1921.

FIG. 42.—Excellent crop of Bosc pears harvested in 1922 in orchard which was protected from frost damage with lard-pail orchard heaters. Same orchard as in Figure 41.

FIG. 43.—Average size of Bosc pear crop per tree in 1922 in orchard protected from frost damage with lard-pail orchard heaters. Compare with Figure 41, which shows same orchard in previous year. Some irrigation.

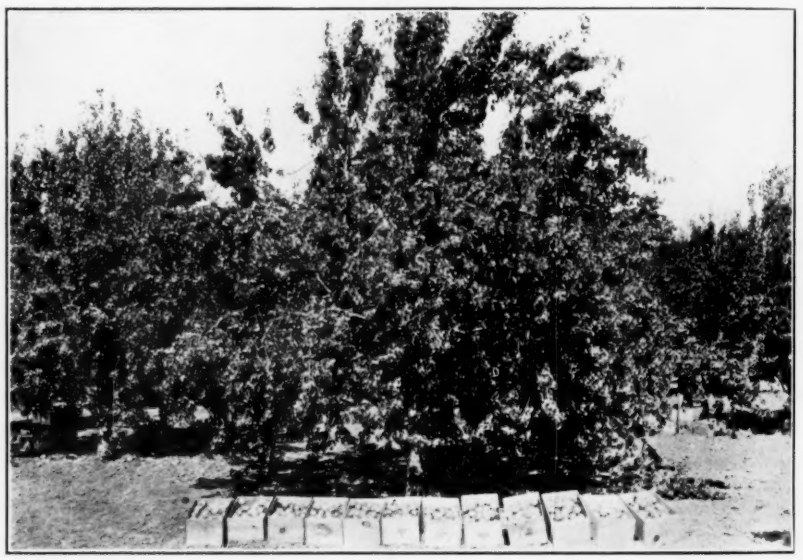

FIG. 44.—Average size of crop per tree of Anjou pears in orchard protected from frost damage with lard-pail orchard heaters, 1921 season. Compare with Figure 46.

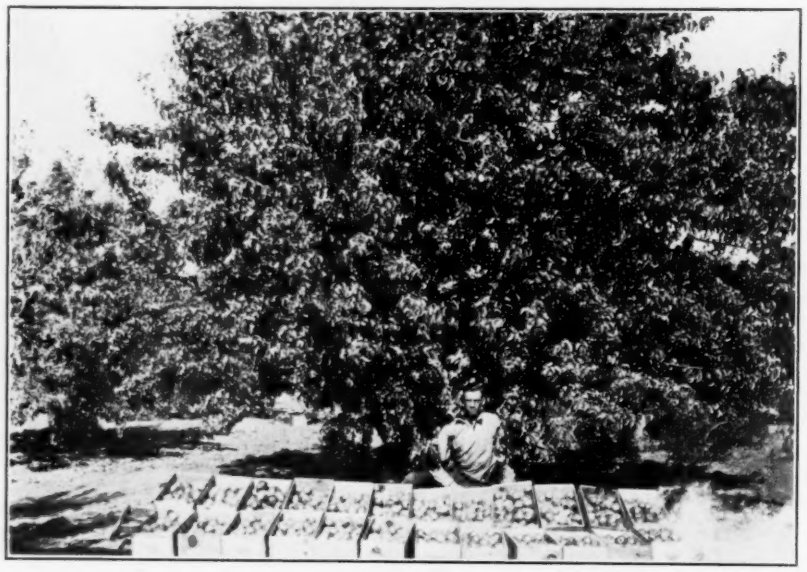

FIG. 45.—Crop of Anjou pears harvested from one of the larger trees in orchard which was protected from frost damage with lard-pail orchard heaters during the 1921 season. Compare with Figure 46.

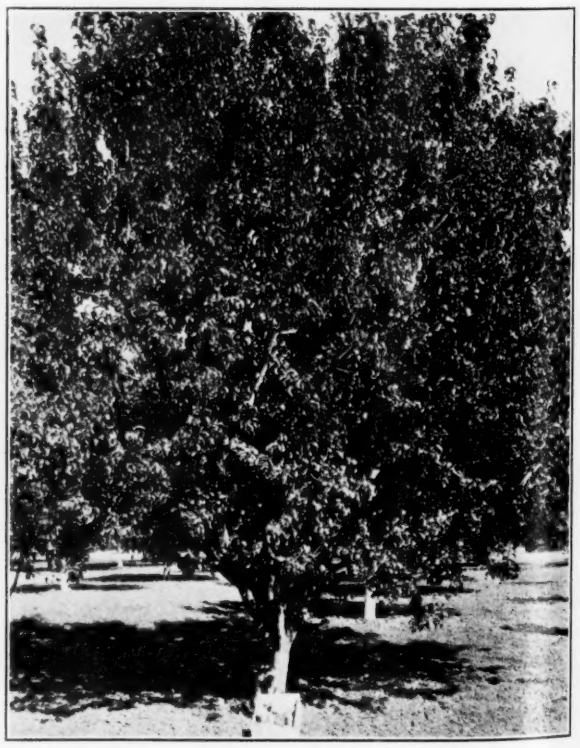

FIG. 46.—Average yield of Anjou pears per tree in 1921 in orchard directly across the road from that shown in Figures 44 and 45. This orchard was not protected from the unusually severe spring frosts, and yielded only about three-fourths box of fruit per tree. Compare size of crop with that shown in Figures 44 and 45.

Bartlett blossoms.—(Same block of trees as above.)

April 12, 1921: Two terminal clusters, containing six blossoms each, in full bloom, were tagged for observation on this date. In each cluster four blossoms show discoloration and two do not appear to be discolored.

May 9, 1921: All pears have dropped from one cluster. In second cluster two apparently vigorous pears remain. Second bloom on tree is now in full bloom. In the cluster from which all the pears have dropped, one tiny new bud has appeared since the fruit has dropped.

June 9, 1921: One pear, badly frost-marked, remains.

August 9, 1921: One pear, badly frost-marked, remains.

Anjou blossoms.—Irrigated trees, 9 years old. Soil, Olympic adobe. Orchard care excellent.

April 12, 1921—Cluster No. 1: Seven blossoms in cluster, all showing discoloration.

Cluster No. 2: Eight in cluster; six show discoloration, and two appear to be in good condition.

Clusters No. 3: Two clusters, with seven blossoms each. One blossom in each cluster appears to be in good condition; others show discoloration.

April 20, 1921—Cluster No. 1: Two fruits seem to be making good growth and appear to be healthy and vigorous.

Cluster No. 2: Three fruits are red and appear to be healthy and vigorous. All fruits in this cluster now show black at calyx ends.

Cluster No. 3: Several fruits are apparently healthy, and are making rapid growth.

May 9, 1921—Cluster No. 1: Only one pear remains and it does not appear to be healthy.

Cluster No. 2: One pear still hanging; remainder have been shed.

Cluster No. 3: Four pears remain. One appears to be healthy and vigorous. The other three are stunted, but are still growing.

June 9, 1921—Cluster No. 1: All fruits have been shed.

Cluster No. 2: All fruits have been shed.

Clusters No. 3: One pear remains.

August 9, 1921: All clusters marked are now bare of fruit. The tree on which they are carried has about one-half box of fruit, most of which is badly frost-marked.

Anjou Fruits.—Irrigated trees, 9 years old. Soil Olympic adobe. Orchard care excellent.

April 20, 1921: Four clusters, containing five fruits each, tagged for observation. Every fruit shows discoloration, but all are making vigorous growth.

May 9, 1921: No fruits are now making normal growth. Dropping off rapidly. Two clusters are bare of fruit. All fruits are seedless and mis-shapen.

June 9, 1921: All fruits have been shed.

Bosc blossoms.—Irrigated trees, 9 years old. Soil Olympic adobe. Orchard care excellent.

In many orchards throughout the valley, more than 90 per cent of the Bosc blossoms were killed by the low temperatures on the nights of April 3–4 and 5–6 (see figs. 12 and 18), while the buds were still tightly closed. These trees came into bloom about April 12. Unless examined closely, the trees appeared to be in perfect condition. There was a great profusion of bloom. However, when the blossoms were examined, from 90 to 100 per cent of the pistils, stamens, and anthers were black and leathery. The ovules did not appear to be injured.

April 12, 1921: Five clusters of Bosc blossoms, every blossom in which has blackened and dried pistils, stamens and anthers, were tagged on this date.

May 9, 1921: Every blossom in every cluster marked has dropped.

NOTES ON SEASONAL DATA.

In studying the effects of the frosts of 1921, it was noted that not only was the crop heavier in the tops of the trees, on account of the difference between the temperature of the air near the ground and that at the elevation of the tops of the trees on frosty nights, but where the damage was not total, the fruit which matured was from terminal clusters of blossoms, which usually bloom considerably later than blossoms in the interior of the tree. This difference between the time of full bloom of blossoms in the interior of the tree and those in terminal clusters is especially marked in the Bartlett and Clairgeau.

In the few orchards which were carefully protected with orchard heaters throughout the frost season the fruit was well distributed throughout the trees.

The terminal blossom clusters are found on long, weak branches, of small diameter, which will hold one or two pears each, at most. These small branches are easily swayed by the wind, and much of the fruit is scarred through limb rubbing in a normal season. Blossoms in the interior of the trees were considerably farther advanced at the time the heavier frosts occurred, and were practically all killed. Thus, the interior of the tree, where the branches were large enough to carry heavy crops. were practically bare of fruit.

The effect of the stratification of the air on frosty nights on the final crop of pears is shown in Figures 30 and 31. Several acres of Comice pears carried a heavy crop of fruit near their tops, but very little fruit in the lower half of the trees. In the tree shown in Figure 30 not one pear was found below 8 feet above the ground. Between 8 feet and 12 feet 39 pears were picked. From 12 feet to 16 feet 112 pears were picked. This condition was quite general throughout the valley, where there was no firing during the 1921 season.

During the 1922 frost season the orchard was protected from frost damage with orchard heaters. At picking time the same tree was examined and the same data as to production gathered. Figure 31 shows the results graphically.

It is well known that blossoms on a young tree are more susceptible to injury by frost than those on an older tree, up to certain limits. To illustrate this fact, two Howell pear trees, side by side in an orchard were selected, one 4 years and the other 16 years old. A count of damaged blossoms on April 12, 1921 showed 4 per cent damage in the older tree and 85 per cent damage in the younger tree. At picking time in the fall the larger tree bore 80 per cent of a full crop, while the crop on the small tree was only 5 per cent of the amount of fruit it should have carried.

OBSERVATIONS DURING THE 1922 SEASON.

The spring of 1922 was very cold and backward and all varieties of pears bloomed from three to four weeks later than usual. Data on the effect of low temperatures in damaging blossoms and young fruit were secured at nine different locations during the season. Most of the temperature stations used in this work were located in the colder parts of the valley. On account of the lateness of the season, there was very little damage to fruit by frost during the spring. The records are of value principally in showing what low temperatures can be experienced, without materially decreasing the size of the final crop in fall. Temperature records for 1922 are shown in Figures 22 to 29.

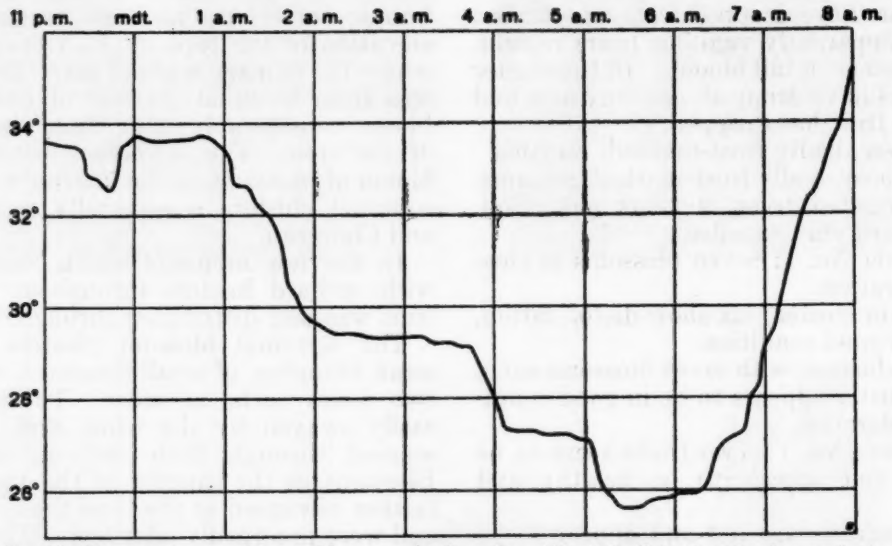

FIG. 22.—Temperature record in a cold pear orchard on the night of April 16–17, 1922, when no heatres were lighted, and temperature records at two stations about one-half mile apart which were almost identical.

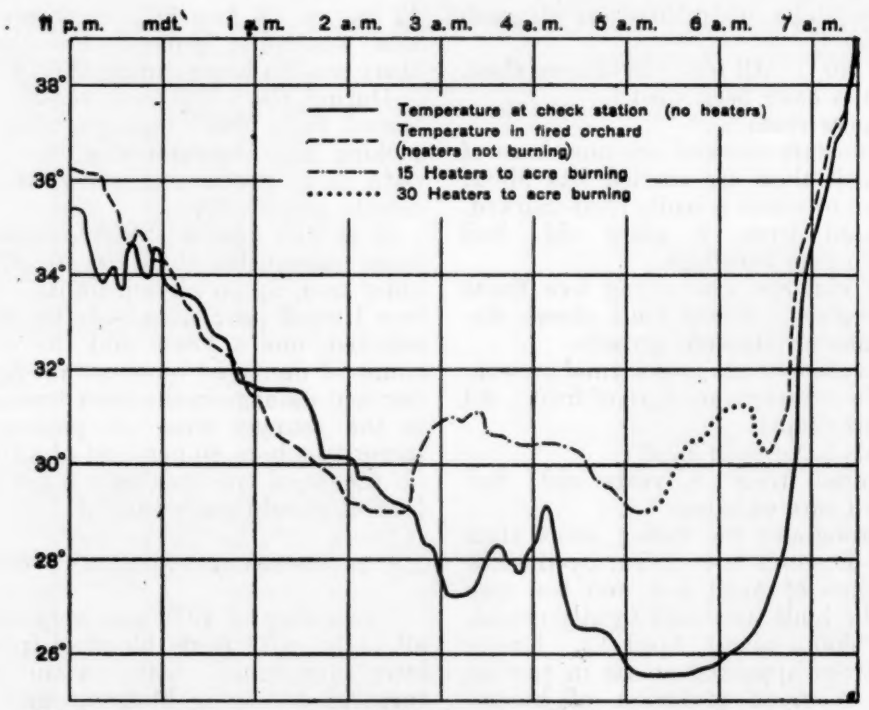

FIG. 23.—Temperature record in fired orchard and in an unprotected orchard, stations one-half mile apart, night of April 27–28, 1922.

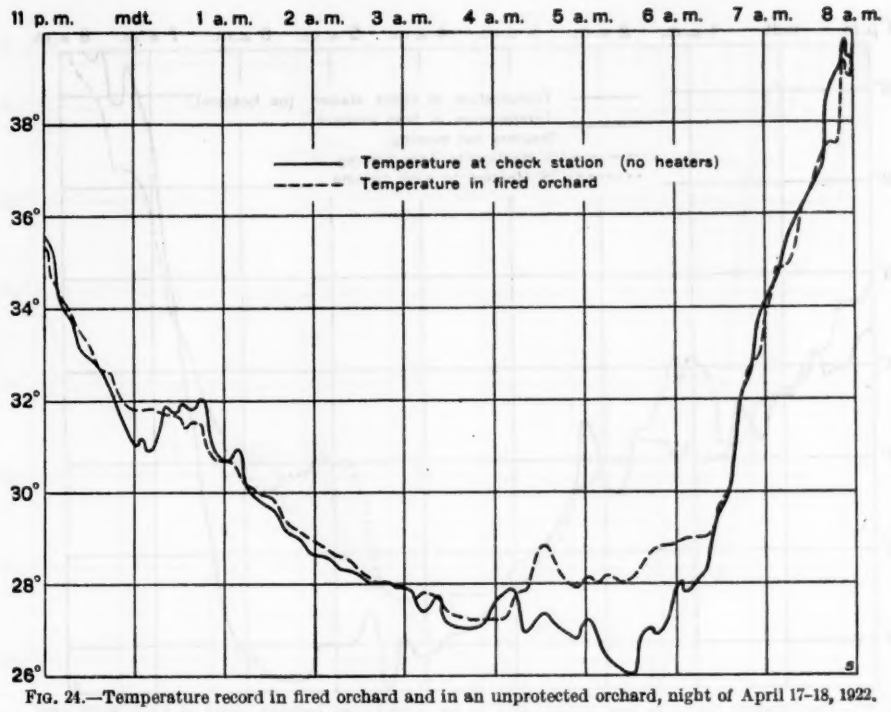

FIG. 24.—Temperature record in fired orchard and in an unprotected orchard, night of April 17–18, 1922.

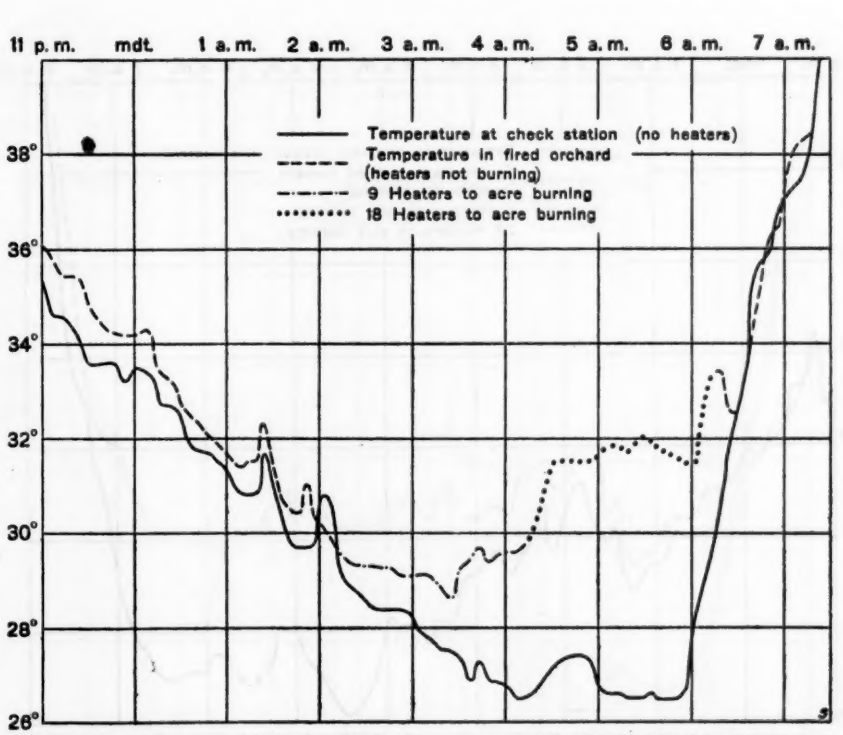

FIG. 25.—Temperature record in fired orchard and in an unprotected orchard, night of April 27–28, 1922. Temperature rose 5½° F. with use of 18 high-stack oil heaters to the acre.

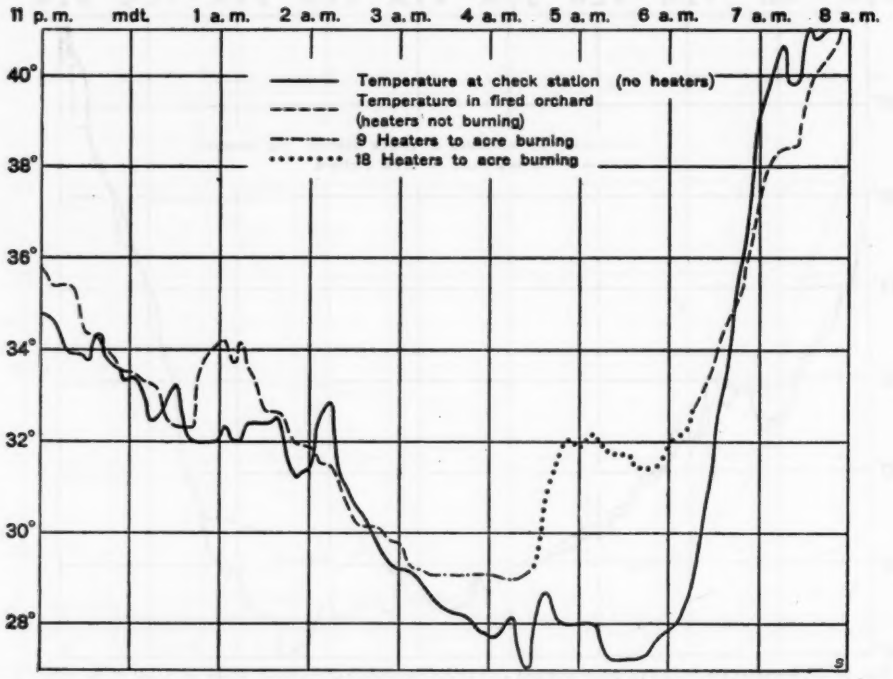

FIG. 26.—Temperature record in fired orchard and in an unprotected orchard, night of April 26-27, 1922. Temperature rose about 4° with 18 high-stack oil orchard heaters to the acre.

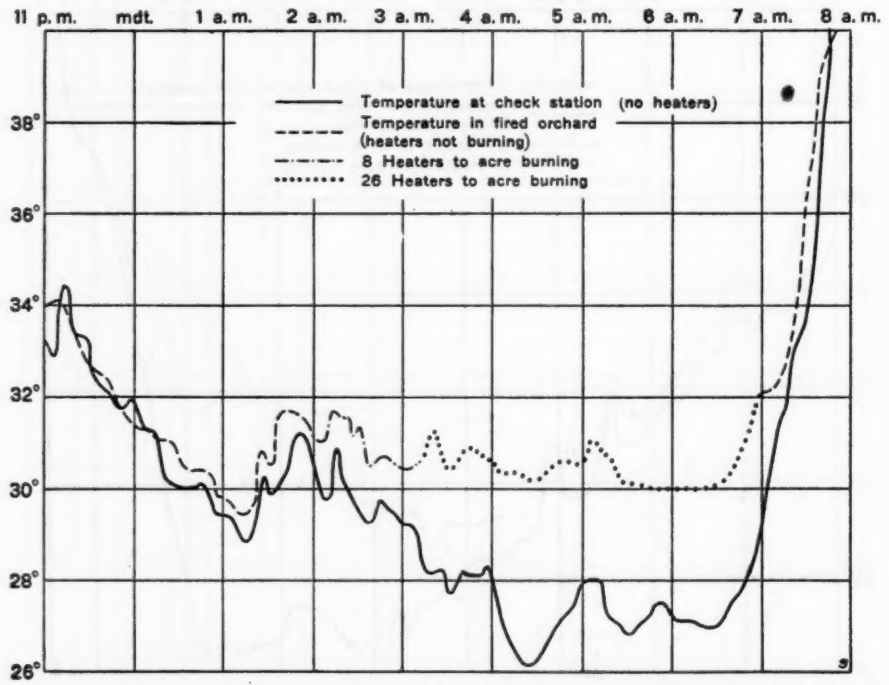

FIG. 27.—Temperature record in fired orchard and in an unprotected orchard, night of April 27-28, 1922. Temperature rose from 3° to 4° with 26 high-stack oil orchard heaters to the acre.

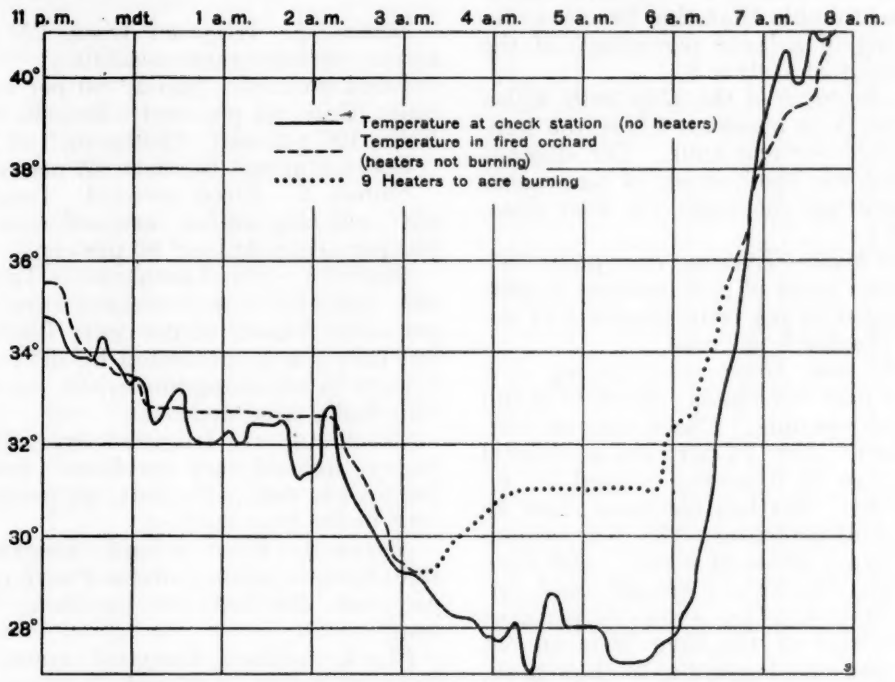

FIG. 28.—Temperature record in fired orchard and in an unprotected orchard, night of April 26-27, 1922. Temperature rose about 4° with nine 5-quart lard-pail oil heaters to the acre.

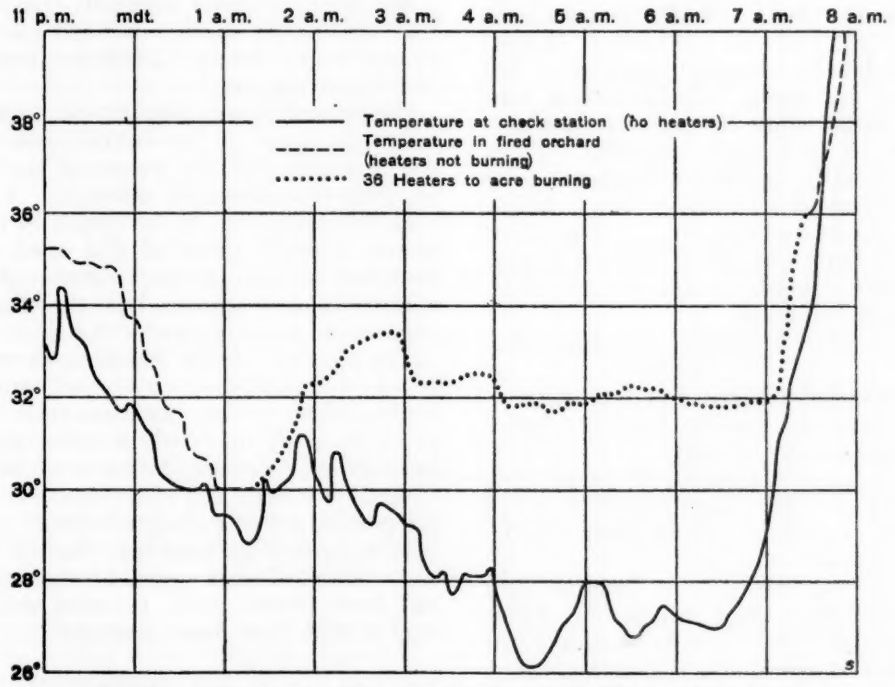

FIG. 29.—Temperature record in fired orchard and in an unprotected orchard, night of April 27-28, 1922. Temperature rose 5 or 6° with 36 5-quart lard-pail oil heaters to the acre.

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The frost of April 16–17 did so little damage that it was practically negligible; it is interesting only for the fact that a few buds were killed while in a very early stage. (See fig. 32.) It seems probable that this frost was responsible for the marking of a large percentage of the Bartlett crop in the vicinity of station 6.

The next frost, on the morning of the 27th–28th, killed the greater portion of the Bosc blossoms where the temperature remained at 25.5° for one hour. The damage caused by this frost, which was the heaviest of the season, is shown in the temperature diagrams for that date. (Figs. 23, 25, 27, and 29.)

Figure 22—Damage to buds.—Evening dew point 33°. Photograph (fig. 32) shows stage of development of pear buds: Anjou buds damaged 18 per cent; Bartlett 11 per cent; Bosc 2 per cent; Comice 4 per cent.

Figure 23—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom; Bartlett in full bloom; Bosc and Comice opening. Check station (unprotected): Anjou blossoms show 24 per cent additional injury, or total percentage of blossoms injured by all frosts to date, 50 per cent. Bartlett blossoms show 26 per cent additional, or total percentage 41; Bosc (young tree) shows practically every blossom killed. Old Bosc tree in adjoining orchard, on higher ground, and undoubtedly somewhat warmer location, shows 81 per cent damage. About 50 per cent of the king buds on old Yellow Newton apple trees, just beginning to show pink, were killed on this date. Fired area: Anjou, Bartlett, Bosc, and Comice blossoms show no additional damage. Bartlett blossoms in same orchard, but not protected, show 52 per cent damage.

Figure 24—Damage to fruit buds.—No damage could be found in the valley, due to this frost.

Figure 25—Damage to pear buds and blossoms.—Evening dew point 29°. Bartlett pears in full bloom; Howell pears slightly past full bloom. Anjou pears past full bloom; Winter Nelis not yet open. Check station (unprotected): Bartlett blossoms show 21 per cent damage; Howell blossoms show 9 per cent damage. Fired orchard: Anjou (large trees) in interior of orchard, near temperature station, show no damage. Small Anjou tree, 6 years old, in interior of orchard, shows 20 per cent damage. Anjou trees, 9 years old, on windward border row, 68 per cent damage. Bartlett and Winter Nelis blossoms show no additional damage.

Figure 26—Damage to pear blossoms.—Evening dew point 32°.

Anjou pears slightly past full bloom; Bartlett pears in full bloom; Bosc and Comice blossoms not yet open. Fired orchard: No damage to any variety.

Figure 27—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom; Bartlett in full bloom; Bosc and Comice opening. Fired orchard: No damage to any variety of pears.

Figure 28—Damage to pear blossoms.—Evening dew point 32°. Anjou pears slightly past full bloom; Bartlett pears in full bloom; Bosc and Comice blossoms not yet open. Check station (unprotected): Bartlett blossoms show 7 per cent injury. Fired orchard: No damage to any variety of pear blossoms.

Figure 29—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom; Bartlett in full bloom; Bosc and Comice opening. (Check station unprotected): Bartlett blossoms show 23 per cent injury. Fired orchard: No damage to any variety of pear blossoms.

EFFECT OF FROST DAMAGE ON FINAL CROPS; 1922 SEASON.

(Percentages of full crops harvested.)

Station 1.—Irrigated trees, 25 years old; soil clay adobe; orchard care excellent.

Fired orchard: Anjou,[2] 80 per cent; Bartlett, 85 per cent; Bosc, 85 per cent; Howell, 100 per cent; Winter Nelis, 100 per cent; Clairgeau, 100 per cent.

Check station: Bartlett, 95 per cent.

Station 2.—Fired orchard: Irrigated trees, 18 years old; soil clay adobe; orchard care excellent. Bartlett, 100 per cent; Anjou,[2] 95 per cent.

Station 3.—Fired orchard:[2]— Irrigated trees, 16 years old; soil clay loam; orchard care excellent. Bosc, 100 per cent; Anjou,[2] 80 per cent; Bartlett (in same orchard, but only partly protected by drift of heat from orchard heaters in adjoining blocks) 95 per cent full crop, 30 per cent badly frost marked.

Check station: Irrigated trees, 14 years old; soil clay loam; orchard care excellent. Bosc, 1 per cent; Anjou,[3] 5 per cent; Bartlett, 40 per cent full crop, 20 per cent badly frost marked.

Station 4.—Fired orchard: Irrigated trees, 10 years old; soil Olympic adobe; orchard care excellent. Anjou,[2] 50 per cent; Bartlett, 100 per cent; Winter Nelis, 95 per cent.

Check station: Irrigated trees, 14 years old; soil Olympic adobe; orchard care excellent. Bartlett, 100 per cent; Howell, 100 per cent.

Station 5.—Fired orchard:[4] Natural subirrigation; trees 15 years old; soil sandy loam; orchard care excellent. Anjou,[2] 20 per cent; Bartlett, 98 per cent full crop, 25 per cent frost marked.

Station 6.— Fired orchard: Irrigated trees, 16 years old; soil sandy loam; orchard care excellent. Anjou,[2] 20 per cent; Bartlett, 100 per cent of full crop, 2 per cent frost marked.

On the night of May 25–26, 1922, a heavy frost occurred in some of the colder spots in the valley. In a few orchards Bartlett pears, of the size shown in Figure 34, were frozen almost through. A few were found with even the seeds frozen, although in most cases the frozen tissue stopped short of the seed cavities. The fruits assumed a dark green, water-soaked appearance, and minute blisters appeared on the skin. A very few fruits were found with cracks in the skin.

Ten clusters of the Bartlett, showing the greatest evidence of freezing, were tagged, and a close watch was kept of them during the remainder of the season. Fully as much fruit matured in these marked clusters as on trees in an adjoining orchard which was protected with orchard heaters, and there was no marked difference in the percentage of high-grade fruit.

It is probable, however, that if the low temperature had continued for a slightly longer time, so that the seeds had been frozen, both the size and quality of the final crop would have been reduced.

CONCLUSION.

The studies conducted in the Rogue River Valley indicate that all the commercial varieties of pears will show slight injury following a temperature of 25.5° F. for

[2] Weather during period of Anjou full bloom was cold and rainy, and very unfavorable for pollination. Small crop due in most cases to this factor, rather than frost damage.
[3] Crop badly injured by frost.
[4] Heaters not fired on one cold night and considerable damage occurred.

about one hour while the buds are showing pink. This also applies to Yellow Newtown apples. The number of buds injured is so slight that the final crop is not affected, in the case of pears, at least. Bosc pears appear to be considerably more susceptible to injury in this stage than other varieties. Winter Nelis pears seem to be more hardy in this stage than any other variety of pears grown commercially in the valley. Winter Nelis also appears to be more hardy while in full bloom than other varieties.

It should be borne in mind that a discoloration of the blossoms or fruit was used entirely as a basis for estimating damage by the different frosts. It is recognized that this is not a perfect method of calculating the amount of damage, as the vital organs of the flower may be injured so that pollination is prevented, without any marked discoloration of the ovules. A sickly yellow color of the pistil was often found following a frost, in flowers which otherwise appeared to be in perfect condition. Whether such a flower was seriously damaged or not, would depend on whether it had been pollinized prior to the frost.

It should be remembered also that all temperatures mentioned in this paper are readings of sheltered thermometers. Unsheltered thermometers, that is, thermometers freely exposed to the sky, would have shown temperatures from one to three degrees lower. Just what the real temperature of the blossoms might be is not known but probably differs from those given.

It was noticed during the 1922 frost season that a temperature of from 25.5° F. to 26.0° F. had been experienced in unprotected orchards, the calyx cups showed a very dry condition; there were no globules of nectar which are found ordinarily. This dry condition and lack of nectar was not found in blossoms in the orchards which had been protected with orchard heaters and the temperature had not been allowed to fall below 28° F.

Whether or not a pear blossom or young fruit will mature after it has been injured by spring frosts to such an extent that the ovules or seeds are blackened depends on the variety. Under the most favorable conditions, probably not more than a very small percentage of blossoms or fruits thus injured will mature. From close observation, covering six frost seasons, it appears that Clapp Favorite, Bartlett, Anjou and Howell pear trees, in the order named, will mature some fruit in which pollination has been prevented or the seeds killed by spring frosts. The Clapp Favorite tree, mentioned on a preceding page, matured four full field boxes of fruit which was entirely seedless as a result of frost injury.

Bartlett trees often set considerable seedless, frost-marked fruit, but usually most of it drops to the ground before the end of the season. The writers often have seen seedless Bartlett fruits remain on the trees until two or three weeks before picking time, and then all fall to the ground within a few days.

In some sections the Bartlett seems to require cross-pollination, and where pollen from suitable varieties is lacking, a fair sized crop of seedless fruit may be matured, even when there is no frost damage. In the Rogue River Valley, so many varieties of pears are grown commercially, in small blocks, there is no lack of pollen for cross-pollination.

Only a very few seedless Anjou pears are likely to be found on the trees at any time. Anjou ability to mature such fruits is much less than in the case of the Bartlett, but an occasional seedless fruit is found.

The Howell seldom matures fruit that has been seriously injured by frost, and Winter Nelis, Comice, and Bosc, practically never.

Usually a small percentage of Yellow Newtown apples which have been severely injured by frost, will mature.

In the case of all the varieties which mature seedless, or nearly seedless fruit, due to frost injury, most of the crop is so marked and misshapen that it is unfit for the market. Pears which are slightly frost-marked are sometimes handled by the canneries, but they are not usually in demand, even for this purpose. The russet rings which form around the fruit, often grow woody toward the end of the season, making them difficult to peel and handle. Figures 35, 36, and 37, show frost-marked fruit and odd shapes assumed by fruits in which the seeds have been killed by frost. Figure 38 shows the difference in appearance between the cross-sections of injured small pears.

In a normal season, Bartlett and Clairgeau blossoms in the interior of the tree, on the older and heavier wood, open several days sooner than blossoms on the ends of the smaller and weaker branches at the outside of the tree. An early frost often kills the interior and earlier bloom, but does not injure the later terminal bloom. In such cases a fairly large crop of fruit may be harvested, but there is danger of breaking limbs off the trees, and the terminal fruit at the ends of the whiplike branches is likely to be scarred by limb rubbing.

CRITICAL TEMPERATURES.

There seems to be no questioning the fact that the generally accepted critical temperatures for pear blossoms do not apply in the Rogue River Valley. The temperature and damage records for the night of April 3–4, 1921 (Fig. 12), is interesting from this standpoint. The temperature was below 32° F. for 14 consecutive hours, and below 28° F. for five consecutive hours, with a minimum temperature of 21.6° F., yet the reduction of the final crop of Bartlett and Clairgeau pears, which were in full bloom at the time, was only from 10 to 15 per cent.

Another point that needs emphasizing is the fact that there is usually a greater difference between the critical temperatures for different varieties of the same fruit than there is between the average critical temperatures for two different kinds of fruit, generally speaking. Judging by the actual yields of fruit in the orchard, which was adequately protected on every cold night except April 3–4, during the 1921 season, there was 15 per cent more damage to Bosc buds, which were barely showing pink and were scarcely separated in the clusters, than to the Bartlett, which was over 90 per cent in full bloom. From a comparison of the final yields of fruit in the fall, there was only 15 per cent more damage to Anjou pears, practically 100 per cent in full bloom, than to Bosc in the pre-pink stage, as mentioned above.

It is impossible to name a definite critical temperature for blossoms or fruit at any stage of development, since the duration of the temperature and the preceding weather and growing conditions must be taken into consideration. Weather conditions on the day following a frosty night also have some influence on the amount of damage.

If an attempt were made to name a critical temperature for fruit buds, blossoms, and immature fruits in different stages of development, even in a general way, it would be

necessary to describe the stage of advancement of the blossoms in greater detail than has been the rule in the past. The three classifications that have been used most generally heretofore are "showing pink," "full bloom," and "petals fallen." From experience in the Rogue River Valley, Bosc pear buds, just before the flowers open, are more easily injured by frost than two or three days later, when the flowers have opened fully. The buds appear to be more susceptible to injury in this stage than in any earlier or later stage.

The amount of damage to fruit buds, blossoms, and immature fruits caused by the low temperatures mentioned in this paper is considerably less than would have been expected based on the critical temperatures which have been generally accepted heretofore. It is recognized that the critical temperatures as determined by the data in the foregoing pages may not apply in other sections of the country. However, the relatively small amount of damage caused by low temperatures, as shown by the data in the preceding pages, can not be said to be exceptional in the case of the Rogue River Valley. The writers have been checking up on the damage to pear blossoms and fruits caused by spring frosts during the past six years, and all the data secured during this period strengthens the conclusion that the generally accepted critical temperatures for pears do not apply in this locality. No careful observations have been made in other fruit-growing communities on the Pacific coast, but interviews with County Horticultural Commissioners and fruit growers in some of the pear-growing sections of California would indicate that experience has been the same there.

Observations of low temperatures during frosts, and their effects on the size and general condition of the fruit crop immediately following the frost and at harvest time, were continued through the spring frost season of 1923. As these observations were made after this paper had been prepared for publication, only a brief reference to them will be made here, to show how they strengthen the conclusions to be drawn from data obtained in preceding years.

OBSERVATIONS DURING 1923 FROST SEASON.

The spring of 1923 was free from unusual weather conditions, and pear trees bloomed at about the average time. There were only a few heavy frosts, and damage was confined entirely to the colder orchards on the lower ground. The statements below show the duration of the low temperatures in several pear and apple orchards after the fruit had set. On April 22 pears were generally about the size of large peas, and by May 2, the date of the last frost of the season, they were about the size of the fruits shown in Figure 47.

Records were obtained in five different orchards, which will be designated by number. In each of these orchards the care of the trees was excellent in every particular. All orchards are irrigated.

Orchard No. 1.—Trees 14 years old; soil clay loam.

April 22–23, 1923.—Lowest temperature 28.3° F. Temperature below 32° F. 4 hours and 25 minutes. Bosc pears were almost uniformly frozen through, and every fruit contained a coating of ice, which could be peeled off, due to frozen dew. Every fruit within sight from ground showed this condition. Anjou pears were generally only partially frozen, probably due to the fact that the foliage on the Bartlett and Anjou trees was considerably heavier at this time than the foliage on the Bosc trees. Observations made about sunrise.

April 23–24, 1923.—Lowest temperature 29° F. Temperature below 32° F. two hours. Bosc, Bartlett, and Anjou pears again frozen, but not through to the core.

April 24–25, 1923.—Lowest temperature 29.2° F. Temperature below 32° F. 3 hours 25 minutes. Bosc, Bartlett, and Anjou pears again frozen, but not through to the core.

April 29–30, 1923.—Lowest temperature 28.7° F. Temperature below 32° F. 3 hours 30 minutes. Practically all fruit within sight from the ground frozen almost to the core. Many fruits badly mottled, but no blistering. Considerable cloudiness toward morning.

May 1–2, 1923.—Lowest temperature 28.2°. Temperature below 32° F. 3 hours 35 minutes. Observations made in afternoon of May 2nd. 95 per cent of the Bosc fruits in the lower portion of the trees have russet rings around their larger ends. About 50 per cent of the fruits show small longitudinal cracks. A very small percentage have slightly discolored seeds.

Anjou pears show a mottled effect quite generally, but no cracks or blisters.

Bartlett pears show general mottling, with some blistering.

Condition of fruit when harvested.—Heavy crop of Bartlett, Bosc, and Anjou pears harvested. About 30 per cent of the Bartlett pears in the lower portion of the trees were frost-marked, the portion of the fruits near the blossom end showing russet. There were practically no misshapen Bartlett pears on the trees.

Bosc pears showed no effects of the spring frosts, except an unusually high russet color, which is an asset to the Bosc.

Anjou pears in the lower portion of the trees showed no effect of the frosts.

Orchard No. 2.—Trees 17 years old. Soil clay loam.

April 22–23, 1923.—Lowest temperature 29.4° F. Temperature below 32° F. 4 hours 30 minutes. Observations made about sunrise. Most of Bosc and Anjou fruits showed freezing almost to the core, and in a few cases, through the core. A very few fruits showed small red spots on the skin. A few others showed a mottling of the skin, but these constituted only a very small percentage of the crop.

April 29–30, 1923.—Lowest temperature 28.3°. Temperature below 32° F. 3 hours 20 minutes. Observation about 15 minutes before sunrise. Anjou and Bosc pears within reach of the ground were almost uniformly frozen through, and about 10 per cent showed raised blisters on the skin.

May 1–2, 1923.—Lowest temperature 29.1° F. Temperature below 32° F. 3 hours 15 minutes. Observations made about sunrise, Bosc and Anjou fruits appeared to be badly frozen, particularly the Anjou. Some clusters were found with every pear frozen through and badly blistered and wrinkled.

Condition of fruit when harvested.—Anjou trees bore a heavy crop of pears, which were of exceptionally fine quality from every standpoint. No evidence of frost damage.

Bosc pear trees bore a heavy crop of fruit, most of which was packed in the extra fancy grade. No evidence of the effects of the spring frosts, except possibly in an unusually heavy russeting, which may or may not have been due to spring frosts.

Orchard No. 3.—Trees 17 years old. Soil clay loam.

April 22–23, 1923.—Lowest temperature 29.3°. Temperature below 32° F. 3 hours 30 minutes. Practically no indication of damage to Anjou pears. Observation about sunrise.

April 29–30, 1923.—Lowest temperature 28.5°. Temperature below 32° F. 3 hours 10 minutes. A large percentage of the Anjou fruits show indications of being frozen about half through, on the exposed sides. Some mottling, but no blistering.

May 1–2, 1923.—Lowest temperature 28.4° F. Temperature below 32° F. 3 hours 35 minutes. Anjou pears and Yellow Newtown apples were carefully examined about sunrise, but there was little indication of damage to either. The apples were about the size of large peas at this time. An occasional Anjou pear was found frozen through, but these were usually the smaller fruits in the clusters. A small percentage of the larger fruits showed frozen spots on the exposed sides, but the freezing did not extend very far into the pears. No blistering whatever was found here. The leaves were large and the foliage heavy, affording considerable protection to the fruit.

Condition of fruit when harvested.—No evidence of the effects of spring frosts on Anjou pears or Yellow Newtown apples.

Orchard No. 4.—Trees 21 years old. Soil sandy loam.

April 22–23, 1923.—Lowest temperature 30.3° F. Temperature below 32° F. 2 hours 25 minutes. No damage to Bosc or Comice pears.

April 29–30, 1923.—Lowest temperature 30° F. No damage.

May 1–2, 1923.—Lowest temperature 28.2° F. Temperature below 32° 3 hours 20 minutes. Observations made on the afternoon of May 2. No sign of injury to the interior of Bosc or Comice pears was found. Bosc fruits, which were exceptionally large in this orchard, showed almost without exception a rather heavy mottling of the skins, but no blistering was found. Comice fruits showed no sign of damage, except for an occasional fruit which showed some slight blistering.

Condition of fruit when harvested.—Heavy crop of both Bosc and Comice pears harvested, with no sign of frost injury to either variety.

Orchard No. 5.—Trees 20 years old. Soil clay adobe.

April 29–30, 1923.—Lowest temperature 28° F. Temperature below 32° F. 4 hours 15 minutes. No indication of damage to Yellow Newtown apples, about the size of small peas.

May 1–2, 1923.—Lowest temperature 27.4° F. Temperature below 32° F. four hours. No indication of damage to exterior of Yellow Newtown apples. About 2 per cent of fruits showed a slight discoloration of the seeds.

Condition of fruit when harvested.—Apple trees were heavily thinned late in May. The final crop of fruit was of high grade and showed no evidence of frost injury.

Most growers of deciduous fruit are rather sensitive on the subject of damage to their crops by frost and prefer to attribute a light crop to almost any other agency than frost damage. "Lack of pollination" is named as the cause of a short crop, when if there had been no frost there would have been no lack of pollination. Figures 39 and 40 show the difference in the appearance of two Howell pear branches about three weeks after full bloom. The blossoms on the branch from an unprotected orchard have made practically no growth since they were injured by frost and are rapidly falling to the ground. The branch from the orchard protected from damage through the use of orchard heaters contains many rapidly growing, vigorous fruits.

PRACTICAL RESULTS OF ORCHARD HEATING.

The different temperature diagrams in the preceding pages of this article show the results obtained on different nights in raising the temperature under actual orchard conditions, with temperatures prevailing outside the fired orchard which would cause damage to the crop. These records were obtained at several different locations in the Rogue River Valley. Five-quart and 2-gallon lard-pail oil heaters and high-stack, 5-gallon capacity oil heaters were used in different orchards.

In every case the thermometers were placed as far from the heaters as possible, and as a general rule the heaters nearest the temperature stations were not lighted.

From an examination of these records it will be seen that it is much easier to raise the temperature on some nights than on others, but on no night during the three seasons covered by these records was there any difficulty in maintaining the temperature above the danger point, using only a fraction of the total number of heaters available.

These records show that it is possible to raise the temperature as much as 8° under exceptionally favorable conditions. However, the average rise in temperature secured with orchard heaters is about 5°. Due to the fact that the layer of cold air near the ground is generally quite thin in the colder locations in a valley, the temperature usually can be raised a greater number of degrees with the same number of heaters at such locations, than in warmer spots on high ground, where the increase in air temperature with elevation is less.

ORCHARD HEATING DURING THE 1921 SEASON.

During the 1921 season the exceptionally severe spring frosts caused such widespread damage to pear crops, an unusual opportunity to note the direct effect of orchard heating on the final crops of fruit was offered. Comparisons between the total amount of fruit harvested in adjoining orchards, protected and unprotected, are given in the following paragraphs:

The greatest damage during the season occurred on the night of April 3–4. A description of the weather on these dates has been given on a preceding page, and temperature records at two locations are shown in figures 12 and 18.

The only 100 per cent crops of pears harvested in the valley in 1921 were those from orchards which were protected with orchard heaters on this night. In order to show that the reduction in tonnage from unprotected orchards was due to frost damage, one of the orchards that were protected with orchard heaters on every cold night during both the 1921 and 1922 seasons will be used as a check. Figure 41 shows the heavy crop of Bosc pears harvested in this orchard during the 1921 season, and figures 42 and 43 show the size of the crop harvested in 1922. The crop was somewhat larger in 1922, but a part of this increase was undoubtedly due to the fact that the orchard was irrigated during the 1922 season for the first time.

A heavy crop of Bosc pears was harvested in 1921 at another orchard, in a very cold locality, which was well protected with orchard heaters.

COMPARISON BETWEEN CROPS IN PROTECTED AND UNPROTECTED ORCHARDS.

Case 1.—A large pear orchard was divided into two smaller orchards and sold to two different individuals in 1920. The owner of one of these divisions protected his trees with orchard heaters in a very efficient and thorough manner. The owner of the other division had all the necessary orchard heating equipment on hand but decided to "take a chance." The type of soil and the care of the trees was the same in both orchards

The orchard equipped with orchard heaters was not protected on the first cold night, April 3–4, and there was heavy damage to blossoms.

Anjou.—Figures 44 and 45 show the size of the crop of Anjou pears in the fired orchard, while Figure 46 shows the average crop harvested in the unprotected orchard.

Bartlett.—The relative size of the crops of Bartlett pears in the protected and unprotected orchards is shown in figures 47 and 48. The fruit in the unprotected orchard was practically all frost marked, while there was practically no marked fruit in the protected orchard.

Bosc.—Sixteen-year-old Bosc trees in the unprotected orchard bore less than 15 per cent of a full crop in 1921, but as there were no protected Bosc trees in the vicinity, it was not possible to make a comparison. However, the owner of this orchard used his orchard heaters to good advantage during the 1922 season, and harvested one of the best crops of Bosc pears in the valley. (See fig. 54.)

Case 2.—Two orchards a short distance apart had been protected with orchard heaters for several years. In 1921 the owner of the higher and warmer of these two decided not to use his heating equipment and did not set the heaters in the orchard. His loss was one of the most severe in the entire valley.

Howell.—On April 12, 1921, a careful check was made on the block of Howell trees nearest the fired orchard, which showed that 98 per cent of the blossoms had been killed by frost up to this time.

The average crop of fruit harvested in this block was estimated at 3 per cent of a full crop. Figures 49 and 50 show the comparative average yields of Howell pears in the protected and unprotected orchards. The heaters in the protected orchard were not lighted on the coldest night of the season, April 3–4, and considerable damage was done. If the heaters had been fired heavily on this night, the difference between the crops in the two orchards undoubtedly would have been much greater.

To show that the normal yield of the trees in the unprotected orchard is large, the average crop secured from the same trees in 1922, when the orchard was protected with orchard heaters and there was little frost to combat, is shown in Figure 51.

Bosc.—A careful check of the Bosc block nearest the protected orchard on April 6, 1921, showed that 45 per cent of the blossoms had been killed. On April 12 scarcely an uninjured blossom could be found.

At the end of the season these trees were practically bare of fruit. Many trees did not bear even one fruit. The average crop harvested from this block was estimated at 2 per cent of a normal crop. There were no protected Bosc trees near by which could be used as a check, but an orchard in a much lower and colder portion of the valley, which was protected with orchard heaters, bore an exceptionally heavy crop of Bosc.

The average crop of pears borne by the same trees which were practically bare of fruit in 1921, is shown in Figure 52.

1922 SEASON.

As has been stated previously, there was very little frost during the 1922 season, and serious damage was confined to the lower and colder spots. The unfired orchard mentioned in case 1, of the 1921 season, is in a very cold location. During the 1922 season the owner, profiting by his experience in 1921, set out the heaviest battery of orchard heaters in the valley. His temperature records, together with those at a neighboring unprotected orchard used as a check on the outside temperature, are shown in Figure 23.

On the night of April 27–28, 1922 (see fig. 23), the blossoms on a 12-year-old Bosc tree at the check station were practically all killed. At the end of the season this tree carried only two pears. Figure 53 is a photograph of a Bosc tree of the same age and size in the heated orchard, showing the heavy crop of fruit. The crop on this tree was representative of the average crop on all trees of like size in the heated orchard.

The average amount of fruit picked from the older Bosc trees in the heated orchard in 1922 is shown in Figure 54. All the trees were breaking down with fruit and could not have matured a heavier crop.

Differences between fruit crops in protected and unprotected orchards were not so great in 1922 on higher ground, but in many instances there was a great difference between the grades of Bartlett pears in fired and unfired orchards. In some unprotected orchards more than 50 per cent of the Bartlett fruits were badly frost marked and misshapen, while in adjoining heated orchards the quantity of marked fruit was negligible.

CONCLUSION.

The effectiveness of the orchard heater, when used properly and in sufficient numbers, in preventing damage to fruit by frost in the Rogue River Valley is no longer open to question. It is possible that extreme cold, accompanied by strong winds, may occur at some future time, and it is possible that orchard heaters may not prove effective in such a case, but from all available weather records it appears that such nights do not occur often.

While all the observations on which this paper is based were made in the Rogue River Valley, it is believed the conclusions regarding the effectiveness of orchard heating, when properly handled, in preventing damage by frost apply with equal force to all the deciduous fruit-growing valleys in western Oregon and in the entire States of California and Washington. Careful study of the matter in the field, outside of the Rogue River Valley, has been confined to the Yakima Valley, in the State of Washington, and the Sacramento and Santa Clara Valleys, in California. Detailed orchard-heating studies also have been made in the citrus districts of southern California. Records secured during the freezes of January and February, 1922, in southern California demonstrated conclusively that orange groves can be protected against outside temperatures of 18° F. by orchard heating, and the protective value of heating is now generally accepted by citrus growers throughout the State.

It is interesting to note that one of the largest pear and apple orchards in the Rogue River Valley has been using orchard heaters during the past 13 years. During that time the fruit crop never has been materially reduced through frost damage, notwithstanding the fact that the orchard is located in one of the coldest spots in the valley.

Until about 1914 fruit growers were attempting to burn heavy crude oil, as it comes from the wells, in the orchard heaters, with the result that the heaters soon filled with unconsumed asphaltum, or the water content of the oil was so high that the heaters boiled over or exploded soon after lighting. At the present time all the larger oil corporations on the Pacific coast are furnishing a special orchard heater oil, from which most of the asphaltum

(To face p. 638.)

FIG. 47.—Average yield of Bartlett pears per tree in 1921 in orchard which was protected from frost damage with lard-pail orchard heaters. The fruit shown in this photograph was carefully examined, and only two pears in the lot showed frost marks. Compare with Figure 48. Out of the first 188 boxes of Bartlett pears picked in this orchard 144 graded extra fancy and 42 graded fancy, with only 2 boxes of culls.

FIG. 48.—Average yield per tree of Bartlett pears in unprotected orchard adjoining that shown in Figure 47 during the 1921 season. More than two-thirds of the crop was so badly frost marked that it was unmarketable as fresh fruit.

FIG. 49.—Average yield per tree of Howell pears in 1921 in orchard which was protected from damage by frost with lard-pail orchard heaters. The heaters in this orchard were not lighted on the first cold night of the season, when the temperature fell extremely low, and a large percentage of the blossoms were killed. The crop probably would have been considerably larger if the trees had been protected on this night. Compare with Figure 50.

FIG. 50.—Average yield per tree of Howell pears in 1921 in unprotected orchard near that shown in Figure 49. The protected orchard was in a lower and somewhat colder location than the unprotected orchard.

(To face p. 639.)

FIG. 51.—Average yield per tree of Howell pears in 1922 in orchard shown in Figure 50. This orchard was protected from damage by frost with lard-pail orchard heaters during the 1922 frost season.

FIG. 52.—Average yield per tree of Bosc pears in 1922 in orchard shown in Figures 50 and 51. Trees were protected in 1922 with lard-pail orchard heaters. Crop from these trees in 1921, when unprotected from frost, averaged less than one-third box per tree, and many trees were absolutely bare of fruit.

FIG. 53.—Young Bosc pear tree (12 years old) in orchard protected with lard-pail orchard heaters in 1922, showing heavy crop of fruit. Bosc tree of same age in adjoining orchard matured only two pears.

FIG. 54.—Average yield of Bosc pears per tree in orchard in cold location protected with lard-pail orchard heaters, season of 1922.

and water have been removed. Since the early days of orchard heating new heaters have been developed, and the growers have equipped themselves with better thermometers; they understand the principles of orchard heating better and are better organized to properly handle the frost fighting.

No thorough, careful tests of the effectiveness of orchard heating under the weather conditions which accompany damaging temperatures during the blossoming period of deciduous fruits in the eastern portion of the United States have been made, so far as the writers are aware. Whether orchard heating will prove to be consistently successful in that portion of the country is highly problematical.

ECONOMIC PHASE OF ORCHARD HEATING.

The writers have confined the discussion of orchard heating in this paper to the question of the practicability of protecting deciduous buds, blossoms, and fruits from damage by spring frosts. The economic side of the question has been purposely ignored, and it will only be touched upon here.

The costs of orchard heating equipment, fuel, etc., vary in different parts of the country, as do the temperatures experienced and the weather conditions which accompany damaging frosts. The grade of fruit produced and prices received for the crops also vary, not only in different districts but in different orchards in the same district.

Obviously, whether orchard heating will pay in a certain orchard will depend on the amount of monetary loss by frost over a period of years and the total cost of protective operations over the same period, including interest on investment, depreciation charge on equipment, and cost of fuel and labor. If the net profit on a crop were the only consideration in determining whether frost protection will pay, the answer would be negative for most if not all the fruit districts of the country. However, when an entire fruit crop is destroyed by frost, the owner's loss is not confined to the net profit he would have made on the crop; the expense of caring for the orchard for a year, interest on the money invested in the orchard, and other similar expenses must be added.

The amount of the loss, therefore, generally speaking, will be the gross value of the crop less the expenses of picking, packing, etc. The loss calculated on this basis is often very large. Many instances have come to the attention of the writers of fruit growers who have saved enough fruit in a single season, or even on a single frosty night, to pay the total cost of equipping the orchard with heaters and auxiliary equipment, together with the expenses of protecting the orchard during the season.

In other words, orchard heating can not be considered on the same basis as fire insurance. Answering a writer who had endeavored to show that orchard heating was unsound from a business standpoint, because the cost was prohibitive when compared to the cost of fire insurance, one of the most successful growers of citrus fruits in California, who has used orchard heaters during the past 12 years, called attention to the fact that if a man was reasonably sure that his house would burn down at least once every 10 years, he would be willing to pay a high premium for insurance.

Another point that must be considered is the fact that whenever a general freeze destroys a large portion of the total crop of a certain fruit, the resulting shortage usually causes higher prices. In such years successful orchard heating usually yields a high return. In many cases this is the factor which makes orchard heating profitable.

The orchards in the United States that sustain sufficient damage by frost to justify the use of orchard heating equipment make up only a very small percentage of the total acreage in fruit trees. Even in the Pacific Coast States orchard heating is generally practiced only in the colder portions of each district.

MOUNTAIN SNOWFALL AND FLOOD CRESTS IN THE COLORADO.

By J. M. SHERIER.

[Weather Bureau, Denver, Colo., Sept. 19, 1923.]

In some respects the situation along the lower Colorado resembles that in the Nile Valley. In addition to the similarity of the soil, climate, and products, a certain amount of water is required each year for irrigation purposes, upon which growing crops are almost wholly dependent and without which there would be a desert. On the other hand, any flood of proportions sufficient to overtop or to break through the principal levees would cause enormous financial loss and endanger many lives. It is not surprising, therefore, that the apprehension felt in western Arizona and southeastern California begins to manifest itself toward the close of every winter in letters and telegrams to the district forecast center, requesting information as to the accumulations of snow in the upper portion of the drainage area, together with the opinion of the forecaster in regard to the prospects of dangerously high water during the following late spring and early summer.

For forecasting purposes, the Colorado drainage area is made up of three divisions. The lower division extends from the mouth of the main stream to Boulder Canyon; the middle division from Boulder Canyon to gaging stations at Elgin, on the Green; Fruita, on the Colorado; and Farmington, on the San Juan. As flood crests due to run-off from the middle division occur early in the season and are not high enough to cause serious trouble, they have not been considered in this discussion.

It must be apparent to all who have had experience in the forecasting of floods that crests produced by melting snow depend not only upon the accumulation of snowfall at the end of the cold season, but also upon the rate at which it is melted and finds its way into the river. In other words, a moderate accumulation in the mountains may disappear so quickly, due to protracted high temperatures, as to cause alarmingly high stages, while unusual amounts of snow at the higher elevations may be taken off by a number of warm periods of only a few days' duration each, followed by weather cool enough to check or to stop the consequent melting. Under the latter conditions, a series of flood crests would result, the highest of which might not be sufficient to cause much alarm. It is not intended to minimize the danger of excessive snow accumulations in the mountains of the upper drainage area at the beginning of spring, but rather to emphasize the fact that the height of subsequent

stages depends largely upon temperature distribution throughout the months of May and June, which, of course, varies from year to year.

During the period from 1900 to 1923 the average crest at Yuma produced by floods that moved down from the upper Colorado was 26.9 feet, gage height. Records of snow depths at stakes now in use at the higher elevations of Colorado are available for the 13 years from 1911 to 1923, inclusive (see Table 1.) Similar records from 18 stakes located on the Green River drainage area in Utah are on hand for the eight years from 1916 to 1923 and for that portion of the Green River drainage area in Wyoming for the nine years from 1915 to 1923.

TABLE 1.—*Average depth of snow on ground in the upper Colorado drainage area at the end of March, together with the resulting combined discharges in the upper Colorado and its tributaries and the discharges and stages at Yuma.*

Year.	Average depth of snow, upper Colorado drainage, Mar. 31.	Departure from the normal for 13 years.	Greatest combined discharge.	Date.	Highest stage at Yuma, May and June.	Date.	Greatest discharge at Yuma, May and June.	Date.	Departure of crest stage at Yuma from normal.
	Inches.		*c. f. s.*				*c. f. s.*		
1911...	[1] 22	−6	80,770	June 10	25.8	June 24	78,300	June 24	−1.1
1912...	[1] 34	+6	139,030	....do....	29.0	June 22	144,000	June 22	+2.1
1913...	[1] 25	−3	69,570	May 31	22.8	June 11	62,500	June 10	−4.1
1914...	[1] 23	−5	137,740	June 3	29.0	June 14 and 15	137,000	June 14 and 15	+2.1
1915...	[2] 22	−17	62,310	June 13	24.0	May 8	66,200	May 8	−2.9
1916...	32	−2	86,030	May 13	25.0	May 23 and 24	74,800	May 24	−1.9
1917...	39	+5	153,200	June 20	29.5	July 1	142,900	July 4	+2.6
1918...	26	−8	118,590	June 15	24.7	June 26	94,300	July 3	−2.2
1919...	21	−13	64,650	May 29	23.4	June 1	57,600	June 6	−3.5
1920...	45	+11	137,940	May 27	30.5	June 8	170,000	June 8	+3.6
1921...	29	−5	169,820	June 16	31.3	June 28	185,700	June 28	+4.4
1922...	43	+9	112,030	May 29	27.4	June 10	115,000	June 10	+0.5
1923...	45	+11	108,830	....do....	25.4	June 9	100,000	June 9	−0.5

[1] For Colorado only.
[2] For Colorado and Wyoming; Utah missing.

There was a deficiency in snow on the ground at the end of March during the years 1911, 1913 to 1915, 1918, 1919, and 1921, with the greatest departure from the average in 1915. In all of these years, excepting 1914 and 1921, the flood crests at Yuma were also below the normal. The maximum stage in 1914, however, was 29 feet, or 2.1 feet above the average, while in 1921 the highest summer stage of record occurred on June 28. In 1916 the snowfall was slightly below normal, and the highest stage in the lower river was also less than the average. In 1912 and 1917, with a snow accumulation considerably above normal, the maximum stages at Yuma were 2.1 feet and 2.6 feet, respectively, above the average flood crest. Excessive accumulations of snow were recorded at the end of March in 1920, 1922, and 1923. In the first of these years one of the three summer stages of record above 30 feet occurred on June 8, when the gauge reading at Yuma was 30.5 feet. In 1922 and 1923, however, although the situation at the beginning of spring seemed especially alarming and much anxiety was expressed by users of the waters of the Colorado and by some of the scientists who were directly interested in the action of the stream, unusually high water failed to result, the maximum stage for the two years being but 27.4 feet on June 10, 1922.

Although the breaking of the levee at Hauser Bend, near Ripley, Calif., in 1922 resulted in the inundation of 30,000 acres, including the important towns of Ripley, Palo Verde, and Rannels, with a property loss that has been estimated at $1,000,000, this local disaster was due more to the weakness of the levee itself than to especially high water, as the stage at the time was not greatly above flood.

In the season just ended, 1923, warm periods were so alternated with temperatures low enough to check the melting at the higher elevations that the crest stage at Yuma was but 25.4 feet, 1.5 feet below the average summer crest, and only 0.4 foot above the flood stage.

To summarize, the crest stages in the extreme lower river agreed fairly well with what might have been expected from the snowfall data in all of the years from 1911 to 1920, with the single exception of the year 1914. During the past three seasons any forecast as to relative stages, based upon snow depths, would have been remarkable failures, especially in 1921 and the current year. The percentage of verification for the entire 13-year period would not have averaged more than 69.

Heavy general rains seldom occur over the upper drainage area at the time when the snow is disappearing most rapidly, but it naturally follows that excessive precipitation here, as elsewhere, will aggravate flood conditions. During June, 1921, a year in which the snowfall at the end of March was considerably below normal, general showers occurred in the upper portion of the drainage area from the 4th to the 9th and on the 14th and 15th, when the upper Colorado and the Green were already in flood. The precipitation which occurred at that time, combined with the effects of unusually high temperatures from the 8th to the 13th, inclusive, produced a stage at Yuma of 31.3 feet on the 28th, as already stated, the highest summer gage reading of record at that place. Failure to make adequate preparation for high water, based upon the deficient snow accumulation in the upper drainage area, would have resulted in a catastrophe in the region of Yuma.

The method of forecasting for the Lower Colorado was devised by Brandenburg and described in the May, 1919, issue of the MONTHLY WEATHER REVIEW, pages 309–311. Briefly, this is based upon the combined discharge at the rating stations at Elgin, Utah, upon the Green, and at Fruita, Colo., upon the Colorado River, together with a discharge for the San Juan that is estimated from the gauge readings made at Farmington, N. Mex. Prior to 1922, about the only checks upon the predictions made for the extreme lower Colorado, based upon the stages and discharges in the upper drainage area, were the stages reported from Topock, Ariz. Owing to frequent changes in the bed of the stream at that place, however, there was a considerable variation in gauge heights for nearly the same discharges. With the establishment, in 1922, of a rating station at Lees Ferry, Ariz., by the Southern California Edison Co., in cooperation with the United States Geological Survey and the United States Weather Bureau, and the subsequent opening of similar stations at the foot of Bright Angel Trail, Grand Canyon, Ariz., and Topock, Ariz., by the United States Geological Survey and the Weather Bureau, it is now possible to check the combined discharge of the Green, the upper Colorado, and the San Juan at least twice and probably three times, depending upon the ability of the hydrographer at Lees Ferry to have his reports delivered to a distant telegraph office before the flood reaches the lower division of the stream. The checks provided by the rating stations at Lees Ferry and the Grand Canyon, especially, during the time these data have been available, have shown the estimates of the combined discharges in the upper drain-

age basin to have been remarkably accurate and reliable. After the middle of May, the time interval between the rating stations at Elgin and Fruita and the gauge at Yuma is about 12 days. By estimating the discharge at the upper stations a couple of days in advance, a general prediction for the extreme lower division of the Colorado can be made two weeks before the occurrence of the crest stage at Yuma. The final check at Topock is made six days in advance of the arrival of the flood crest at Yuma.

Forecasts based upon these data are sufficiently accurate for all practical purposes, usually to within a few tenths of a foot at the time of the highest water of the season. It does not seem possible, therefore, under the present conditions for any flood to pass from the upper reaches of the Colorado to the Imperial Valley without the distribution, nearly two weeks in advance, of such warnings as will prepare all interested persons to meet the emergency. It is not safe to attempt to make predictions for a longer period.

FLOOD OF OCTOBER 22–25, 1923, IN CANAL ZONE.[1]

By R. Z. KIRKPATRICK, Chief Hydrographer.

[Balboa Heights, Canal Zone, Nov. 23, 1923.]

The week previous to the flood, Isthmian weather conditions were influenced by a West Indian hurricane, reported as central between Colon and the Island of Jamaica. Strong south and southeast winds were experienced and unusually dry weather for this season of the year occurred. Whether or not the hurricane had any influence on the extreme rainy period that followed is conjectural; however, as soon as the center of the disturbance had moved northward sufficiently that it no longer caused prevailing southerly winds, normal direction of northerly and westerly winds was again recorded; their velocity increased and conditions of the "norther" type began.

Rainfall.—Early Sunday morning, October 21, rain began to fall and continued with few breaks until Saturday, October 27. The temporary lull in the storm that occurred on the 23d was a very fortunate occurrence, in that it gave a few hours for lowering the already high level of the lake and thus facilitated the handling of the enormous quantity of water that came in on the 24th. Previous rainfall records were broken and new maxima established at several stations north of the Continental Divide. The following table gives the amount of rainfall recorded at selected stations during the storm period:

Rainfall (inches).

Date.	Porto Bello.	Colon.	Gatun.	Monte Lirio.	Gamboa.	Alhajuela.	Vigia.	Pedro Miguel.	Balboa Heights.
Oct. 21....	1.48	4.26	4.58	4.94	1.88	0.89	0.34	0.57	0.36
Oct. 22....	3.27	9.02	9.09	6.84	6.75	7.33	7.40	3.64	3.14
Oct. 23....	5.43	4.23	3.36	5.02	1.89	2.81	3.54	1.09	.88
Oct. 24....	4.17	10.03	10.99	7.97	4.64	8.22	7.51	3.65	2.98
Oct. 25....	1.96	1.76	.63	1.58	.35	.34	.38	.09	.04
Oct. 26....	3.78	5.94	3.98	4.58	.90	.16	.57	.10	.01
Oct. 27....	1.56	.71	2.54	4.04	2.06	1.75	2.17	.69	.35
Total.. .	21.65	35.95	35.17	34.97	18.47	21.50	21.91	9.83	7.76

A maximum 24-hour rainfall of 12.25 inches was recorded at Gatun from 7:34 p. m. on the 23d to 7:34 p. m. on the 24th. This breaks all records for 24-hour isthmian rainfall, the previous maximum being 10.86 inches at Porto Bello on December 28–29, 1909.

In order to give a comparison of the recent flood with that of December, 1909, the following table showing rainfall for this period is furnished below:

[1] See MO. WEATHER REV., Oct., 1923, 51:530.

Rainfall (inches).

Date.	Porto Bello.	Colon.	Gatun.	Monte Lirio.	Gamboa.	Alhajuela.	Vigia.	Pedro Miguel.	Balboa Heights.[1]
1909.									
Dec. 26....	5.55	3.69	3.99	5.35	2.66	5.56	2.25	2.12	2.16
Dec. 27....	2.21	1.85	3.84	1.00	1.10	1.70	(2)	2.31	1.31
Dec. 28....	3.64	.50	.21	.62	.32	3.49	.....	.06	.06
Dec. 29....	7.96	.36	.30	.10	.34	1.09	.....	.06	.20
Dec. 30....	4.94	3.29	2.36	2.77	2.18	2.91	.....	2.25	1.16
Dec. 31....	1.07	.40	.84	.18	.08	.02	.....	.05	.08
1910.									
Jan. 1.....	3.02	1.13	.97	.78	.30	.24	.....	.36	.03
Total....	28.39	11.22	12.51	10.80	6.98	15.01	.....	7.21	5.00

[1] Station then Ancon. [2] Station washed out at 8 a. m., 26th.

A comparison of the two tables shows that while the rainfall at the headwaters of the Chagres and Pequeni Rivers was lower during the recent flood, the rainfall over the Gatun Lake area, especially the northern end, was about three times as heavy as during the 1909 flood period.

THE CHAGRES RIVER.

Alhajuela.—A slight rise on the Chagres occurred in the early morning of the 21st, but the crest was soon reached and the river dropped to elevation 93 feet and continued near this elevation until the beginning of the big flood. At 9 a. m. on the 22d, the river began to rise rapidly, continuing to rise steadily until 10:30 p. m., when a crest of 117.40 feet was recorded. The crest of the flood really lasted from about 9 p. m. until 12:30 a. m., after which it fell about as fast as it had risen, reaching 99.20 feet at 6:30 p. m. of the 23d. A second and slower rise then began, reaching elevation 112.80 feet at 4:30 p. m. of the 24th. This second crest was of shorter duration, lasting from 4 to 5 p. m., after which the river dropped about as rapidly as it had risen, and was at elevation 101 feet by 7 a. m. the morning of the 25th. From this point the drop in the river was very slow.

Vigia.—At Vigia the initial height of the river was 128.40 feet at 8 a. m. of the 22d. The rise in the river began about 45 minutes earlier than at Alhajuela. No record was obtained after 6:45 p. m., owing to the instrument house being flooded. Telephone communications between Alhajuela and Vigia were also severed about this time and nothing further was heard from Vigia

until several days later. All the rods with the exception of the upper one, were either washed away or overturned. The observer at Vigia, however, obtained a crest height of 167.80 feet on the upper rod around 10 p. m. of the 22d.

Calle Larga.—An actual gauging made with current meter between 8:05 and 8:30 p. m. of the 22d with the river at elevation 129.20 feet (116.65 feet at Alhajuela) showed a maximum surface velocity in midchannel of 11 miles an hour and a discharge of 101,190 cubic feet per second. Judging from this gauging the river at its maximum height of 117.40 at Alhajuela was probably discharging 108,800 cubic feet per second.

Limon Plantation.—On the peninsula formed by the junction of Chagres and Gatuncillo Rivers the flood reached a crest height of about 105 feet. This height was due partially to the Gatuncillo, which was in high flood. The Limon Commissary was swept away about 7 p. m. of the 22d. Below the mouth of the Gatuncillo the crest of the flood was not so high, the water stage register, located a short distance below, showing a crest height of 102.20 feet. Fifteen thousand banana trees were washed out at Limon Plantation and other damage done.

Juan Mina.—Juan Mina, in normal river stages a part of Gatun Lake, really became a part of the Chagres River during the flood. The water was 16 inches deep on the floor of the commissary. What part the Chilibre River had in causing the stage at Juan Mina is not known. It was probably discharging as much water in proportion to its size as the Gatuncillo.

Comparison with 1909 flood.—Calculations based on the gauging obtained at Calle Larga indicate that from 4 p. m., October 22d, to 8 a. m., October 23, approximately 5.121 billion cubic feet of water passed Alhajuela, and for both flood periods, 9 a. m. October 22, to 12 midnight, October 27, approximately 14.290 billion cubic feet or 66 per cent of the total October Chagres flow occurred. Applying our present discharge curve to Alhajuela gauge heights during the flood period of December 26, 1909, to January 1, 1910, we find that from 10 a. m., December 26, to 4 a. m., December 27, 7.282 billion cubic feet of water passed Alhajuela; and for the flood period from 7 a. m., December 26, 1909, to 12 midnight, January 1, 1910, approximately 20,000 billion cubic feet came down the Chagres. Roughly the October flood of 1923 was 70 per cent of the greatest flood on record, that is, as far as the Chagres River above Alhajuela is concerned.

GATUN LAKE.

Gamboa.—Like Juan Mina, Gamboa is at present a part of Gatun Lake, but during the extreme flood period—that is, while the Chagres was near its crest height—it became in some respects a part of the river, for a maximum velocity of 10 miles an hour was recorded here and canal traffic would have been impossible from 5:30 p. m. of October 22 to 10 a. m. the following morning. Dredging operations were suspended and a tug could not pass the bridge at 9 p. m. with the current running 7.4 miles per hour. Heavy driftwood passed the bridge during the evening of the 22d and the bridge boom was broken. Canal traffic continued during the minor flood of the 24th, but the S. S. *Agwistone* went aground on the west bank near Gamboa shortly after noon. Traffic was suspended at about 6 p. m. in order that the lock culverts could discharge water. A maximum elevation of 88.42 feet was recorded at 1 a. m. of the 22d and a secondary maximum of 88.25 feet was recorded at 5:30 p. m. of the 24th. Current measurements at Gamboa with a current meter were impossible, but the float method was used over a course of 175 feet. A report in detail of the currents at Gamboa Bridge has been made.

Pedro Miguel.—The lake height at Pedro Miguel followed closely the rise in the lake at Gamboa, Gaillard Cut being in many respects a backwater arm of the Chagres flow, but surges in the cut superinduced by Pedro Miguel lockages aggravated the already high elevation; shortly after midnight of the 22d–23d and again on the afternoon of the 24th water began to pour through the strut slot into the bull wheel pits at Pedro Miguel Locks. A maximum height of 88.85 feet was recorded here at 5:15 p. m. of the 24th. An elevation of 88.65 feet occurred at 12:20 a. m. of the 23d.

Monte Lirio.—The lake height at Monte Lirio was influenced locally by the discharge of the Gatun, Agua Sucia and Agua Clara Rivers, which must have been in high flood. A maximum height of 87.75 feet was recorded on the afternoon of the 24th and an elevation of 87.60 feet occurred during the morning of the 23d. No data regarding currents under the Monte Lirio bridge are available; ocular reports say they were considerable.

Gatun.—The lake began to rise at 8 a. m. of the 22d, with an initial height of 86.16 feet, and continued to rise steadily, irrespective of spillway and lock culvert discharge, until 7 a. m. of the 23d, when an elevation of 87.48 feet was reached. A temporary lull in the storm allowed the lake level to be reduced to an elevation of 86.78 feet by 3:30 a. m. of the 24th. Closing of the lock culverts and resumption of canal traffic on the morning of the 24th, with the incident reduction in discharge of 36,000 c. f. s., together with a continuation of the storm, caused the lake to rise again, until a maximum elevation of 87.58 feet was reached by 9 p. m. The main part of the storm having spent itself by this time, the lake began to fall (due to the heavy spillage) and continued to drop until it had reached an elevation of 85.86 feet by 9 p. m. of the 26th. From this time it was allowed to rise slowly and held around 86 feet. The rise in the lake during the flood period was equivalent to a storage of 6.5 billion cubic feet.

Gatun Spillway.—At 6:36 a. m., October 21, two spillway gates were opened to take care of the lake's inflow. By 8 a. m. of the 22d no appreciable increase in elevation had occurred, but soon after the lake began to rise steadily. The situation was reported and permission obtained to open more gates. Two more gates were opened at 1:45 p. m., another at 3:20 p. m., one at 4:22 p. m., one at 4:34 p. m., one at 5:28 p. m., one at 7:12 p. m., one at 11:26 p. m., making a total of 10 gates running during the latter part of the night of October 22–23. An eleventh gate was opened at 8:51 a. m., October 23. This gate, in connection with two others, was closed at 11:30 a. m. of the 23d, leaving eight running. The eight gates continued to discharge steadily, and at 10:57 a. m. of the 24th a ninth gate was opened and left running until 1:21 a. m. of the 25th. The major part of the storm being over, the eight gates were continued in operation to reduce the lake elevation and closing began on the evening of the 25th. By the 28th it was possible to close all of the gates. An enormous quantity of water was discharged by the spillway during the flood. A maximum momentary discharge of 155,430 c. f. s. occurred during the time 11 gates were

open and during the 24-hour period from 7:12 p.m., 22d, to 7:12 p.m., 23d, 11.03 billion cubic feet of water was discharged. During the flood period, from October 22 to October 27, inclusive, 42.4 billion cubic feet of water was wasted over the spillway. This represents one and one-third times as much water as that contained in the lake between elevation 80 and 87 feet.

Gatun and Pedro Miguel Lock culverts.—Gatun and Pedro Miguel Lock sidewall culverts ran from approximately 9 p. m. of the 22d to 3 p. m. of the 23d, from 11.30 p. m. of the 23d to 7.45 a. m. of the 24th, and from 6 p. m. of the 24th to 10.30 a. m. of the 25th, discharging approximately 36,000 c. f. s. and a total of 5.4 billion cubic feet during the flood period. This amount of water is equivalent to 1.2 feet in Gatun Lake.

The Mindi Dike.—A limiting controlling feature of spillway gate operation was the condition of the Mindi Dike, more than eight gates running being considered dangerous in so far as the dike was concerned. However, with 9 and 10 gates open it stood the strain and for over 2 hours held against the maximum discharge of 155,430 c. f. s. when 11 gates were running.

Telephone communications.—With the exception of the line from Alhajuela to Vigia, no break occurred in communications until about 1 p. m. of the 24th, when a landslide north of Pedro Miguel severed all telephone communications. Hardly a half hour passed before the electrical division had arranged for wireless communications and this scheme was adopted until by 6:30 p.m. a temporary line was run around the slide and communications were resumed through Gamboa. Reports were received from Gatun over the automatic line and relayed to Balboa from Gamboa. By 1 a. m. of the 25th the temporary line was replaced by permanent line, and by 4:30 a. m. direct communication with Gatun was again established.

Total yield during flood period.—The amount of water that came into Gatun Lake during the flood period can be determined only approximately, owing to the uneven surface of the lake. The following table shows these approximate figures that were obtained by using lake values at Gatun and known requirements and discharges:

Probable Gatun Lake total yield (midnight to midnight).

Date.	Billion cubic feet.	Cubic feet second.	Date.	Billion cubic feet.	Cubic feet second.
Oct. 22	10.035	116,200	Oct. 25	5.159	60,000
Oct. 23	10.238	118,500	Oct. 26	3.550	41,000
Oct 24	15.016	173,800	Oct. 27	3.985	46,000
			Total	47.983	[1] 92,600

[1] Average.

This total represents 1½ times as much water as that contained in the lake between elevation 80 and 87 feet. It is probable that during the maximum rainy periods a momentary inflow as high as 250,000 to 300,000 c. f. s. occurred.

From a comparison of rainfall records of the flood periods of 1909 and 1923, it will be seen that over Gatun Lake the rainfall was about three times as heavy in 1923 as in 1909. This would indicate that the inflow over this region was probably three times as great as in 1909. Using this fact as a basis for a comparison of the two floods, a rough estimate of 1909 is possible. Assuming 300,000 c. f. s. as the probable 1923 flood maximum momentary inflow and knowing that approximately 100,000 c. f. s. came from the Chagres, 200,000 c. f. s. then was the inflow over Gatun Lake area other than the Chagres. If this value was three times what it was in 1909, in 1909 then 67,000 c. f. s. was the probable maximum momentary yield of the lake area. In 1909 approximately 154,000 c. f. s. was the maximum momentary yield of the Chagres above Alhajuela. 154,000 + 67,000 = 221,000 c. f. s. probable maximum momentary yield of the 1909 flood. In other words, the 1923 flood was to the 1909 flood as 300 is to 221, or roughly there was one-third more water momentarily that came into Gatun Lake during the 1923 flood than there would have been in 1909 had there been a Gatun Lake.

In using the above figures it must be remembered that at best they are only rough approximations and should be considered as such. Anyhow, it is sure that this was preeminently a Canal Zone flood as to origin. The 1909 one largely originated in the upper Chagres. It appears that a combination flood would require careful and prompt attention to protect canal structures.

IS THERE AN ANTITRADE WIND IN THE EQUATORIAL REGIONS?[1]

By Rev. S. SARASOLA, S. J.

[Observatoire National, Bogota, Colombia, Oct. 20, 1923.]

General circulation of the atmosphere.—In the discussion of the general circulation of the atmosphere writers frequently classify the winds as trade and antitrade. In the Northern Hemisphere the former blow from the northeast in the strata nearest the surface of the earth. On the other hand it is said that in the high regions of the atmosphere the antitrade winds move in the opposite direction, from the southwest, to complete in this manner the circulation of the currents.

We do not intend to study here the influences that are attributed to the earth in the deflection of the trade winds, such as the effect of the motion of rotation, nor shall we investigate the causes of those currents; our purpose is to inquire whether the observations that we have from the equatorial and tropical regions prove the existence of an antitrade in the Northern Hemisphere as has been written again and again since the meteorologis Dove advanced that theory almost a century ago.

What arguments lead the writers to verify the presence of that upper current or antitrade which blows, according to them, from the southwest? These can be summarized under two headings: 1. The direction of the smoke from some volcanoes and the ashes carried by that equatorial current; 2. The direction of the elevated currents of cirrus and cirro-stratus clouds which, as those writers affirm, must be from the southwest.

Since this observatory (*Observatorio Nacional de S. Bartolemé*, Bogota, Colombia) is situated at an elevation of 2,645 meters on the *cordillera* of the Andes and since there are available observations for almost a year in addition to those published by Rev. L. Gangoiti, S. J., director of the Observatory of the College of Belén,

[1] Translated from manuscript text in Spanish by W. W. Reed, Washington, D.C., October 30, 1923.

Havana, in the paper "*Circulación general de la atmósfera*," we have believed it opportune to analyze those data to see if in reality the theory of the antitrade is based upon indisputable facts. It is to be noted that the books on meteorology contain categorical statements, but do not give data that confirm them.

Arguments against the antitrade wind.—To prove the existence of the upper antitrade wind the writers refer to the ashes that the volcanoes have thrown out in some eruptions, instances of which are given, for example, in the work on meteorology by A. Angot. This argument is very much lacking in force, since the data are very few.

Moreover, various observations of this phenomenon prove entirely the contrary; that is, that the antitrade, or the equatorial current of Dove, does not exist.

With reference to the volcano Cotopaxi a letter written by Father Sodiro, S. J., to the director of the Belén Observatory merits attention.

"The eruption began about 6 a. m. on the 26th of June (1877), hurling up a black column which on account of the stillness of the atmosphere rose vertically to the height of 8,000 to 9,000 meters above the level of the crater. Thence through a current of air that was moving from the east it was directed toward the western *cordillera*, but the fine dust that formed a dense cloud began to darken the air to a great distance from the volcano. At 8 a. m. the wind suddenly changed and blew toward west-northwest; the cloud of dust which until then filled the atmosphere only to the south of Quito was reaching that city. At that hour the darkness in Quito was that of the beginning of a night without moonlight; at 2 p. m. there was complete darkness, and between 3 p. m. and 4 p. m. it was such that one could not see his hand before him and people were stumbling against one another in the streets. The light from the street lamps extended hardly to a distance of 2 meters.

"This darkness and the ashes that caused it extended from the southwest to the northwest of the volcano; in Ambato (75 miles south of Quito) there was observed only the immense cloud which extended over the Province of Leon and reached toward the west as far as the Pacific Ocean."

If it is added that on not a few days in 1907 and 1908 the smoke from the volcano of Cotopaxi moved from the second quadrant and occasionally from the west we shall be of the opinion that the eruptions of the Ecuadorian volcano do not prove the existence of the antitrade wind.

Nor does the volcano of Colima (in Mexico), which has an altitude of 3,960 meters, throw its smoke from the southwest. During almost nine months the prevailing current is from the second or from the fourth quadrant, only in March and sometimes in February is it from the southwest.

And what is to be said of the result obtained from the observations of the highest clouds? It is true that the data for Bogota embrace hardly an entire year, but just like those for the other points these confirm the same conclusion, namely, that the upper antitrade does not exist. Let us summarize these observations.

Observations in Ecuador and the tropical regions.—We begin with those made at Quito made by Father Harbach, S. J., who noted the direction of the cirrus clouds for 38 months. Also at Riobamba and Pifo observations of the highest clouds were made in the years 1908, 1909, and 1910. The result that is derived from all these in that indicated by Father Gangoiti in his paper.

Quito and Riobamba are in fact in the Southern Hemisphere, but here they can be considered in the Northern Hemisphere, since at both places the upper current from the northwest or southwest ceases to be dominant, the cirrus clouds moving by far most frequently from the first quadrant and with decreasing frequency from the second, fourth, and third quadrants. Father Herbach stated in one of his letters that the cirrus clouds move from the northeast almost without exception during the entire year.

We are of the opinion, then, that this current of the antitrade does not exist in the limits of Ecuador as many writers have theoretically supposed.

Observations at Bogota.—In the observations made every two hours for one year at the new *Observatorio Nacional de S. Bartolomé* very careful study has been given to the directions of the cirrus and cirro-stratus clouds, also to those of the intermediate and lower clouds. The elevation of the observatory above sea level is 2,645 meters. Here is the result of the observations.

In the months of October, November, and December the upper currents move from the third quadrant very rarely; in the following months they have this direction somewhat more frequently. On the contrary the frequency with which they move from the second quadrant is rather great, and there is a tendency toward movement from south, especially in the month of March. Hence neither do the observations at Bogota give us sound arguments in favor of the antitrade.

The reader will desire, perhaps, to know what dircetion the intermediate and lower clouds have on this *cordillera* of the Andes. It can be stated that in this region of the atmosphere, too, the usual currents move from the second quadrant, although they sometimes undergo slight deviation. In the rainy season the winds nearest the surface shift somewhat, blowing from the west at the approach of the squalls.

What is to be said of the atmospheric circulation observed in the subtropical regions extending to the north of Colombia? If we analyze the nephoscopic data published in Washington and the studies that we have relative to the highest currents over the islands of the Caribbean Sea, comparing at the same time the cyclonic and anticyclonic circulations, we shall be of the opinion that even here there do not exist convincing arguments in favor of the upper current known by the name antitrade.

From the data on the upper currents furnished by the Weather Bureau at Washington and relating to nephoscopic observations the following conclusions may be reached.

On the island of Trinidad the highest clouds move approximately from the west during the months January to May, inclusive, November, and December, and from the east during the hurricane season. The westerly current is most constant at Curaçao, where the clouds move from the easterly direction only in the months of July and August.

Also in the Barbados, Dominica, and St. Kitts the current is at times from the west, but not from the southwest. According to Maxwell Hall the cirrus clouds

move from east-northeast in the hurricane season. We shall not omit mentioning the direction that the upper clouds have at San Juan, Porto Rico. In general it can be stated that the current from the second quadrant predominates, the times at which the southwest direction is observed being relatively few.

There will hardly be found a series of observations of clouds so extended and so complete as that of the observatory at Belén College, Havana. The currents of the atmosphere have been observed very carefully at intervals of two hours during a period of 50 years or more.

In the paper that its director, Father Gangoiti, published in 1904 we find the following results for the period 1892–1902.

Mean direction of upper clouds at Havana, from the observations for 11 years (1892–1902).

	Cirrus.	Cirro-stratus.		Cirrus.	Cirro-stratus.
January	S. 81 W.	S. 79 W.	July	N. 28 E.	N. 52 E.
February	S. 83 W.	S. 80 W.	August	N. 48 E.	N. 54 E.
March	N. 88 W.	S. 89 W.	September	N. 27 E.	N. 89 E.
April	N. 89 W.	S. 89 W.	October	N. 87 W.	S. 61 W.
May	N. 83 W.	S. 84 W.	November	S. 77 W.	S. 72 W.
June	N. 49 W.	N. 84 W.	December	S. 80 W.	S. 73 W.

Conclusion.—There do not exist sound arguments in favor of the theory of the antitrade wind as advanced by many writers. In the observations in Ecuador, Bogota, Mexico, and the Antilles that upper current is not found to be constant and permanent.

THE DEVELOPMENT OF METEOROLOGY AS ILLUSTRATIVE OF THE RÔLE OF MATHEMATICS IN THE PROGRESS OF SCIENCE.[1]

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., Dec. 10, 1923.]

Mathematics plays a singularly fundamental rôle in all domains of exact scientific thought. In the words of Spottiswoode,[2] "Conterminous with space and coeval with time is the kingdom of Mathematics; within this range her dominion is supreme; otherwise than according to her order nothing can exist; in contradiction to her laws nothing takes place. On her mysterious scroll is to be found written for those who can read it, that which has been, that which is, and that which is to come." An irrefutable proof of this claim is provided by an analysis of the rôle which mathematics has actually played in the development of the sciences,[3] and in the present paper we shall use the history and present status of the science of Meteorology as an illustration.

Man quickly finds by experience that his greatest good and comfort come from an understanding of the environment in which he finds himself—as Bacon said, Knowledge means power and control over Nature; besides, he naturally feels an innate longing to know the explanations of the phenomena that he sees going on about him.[4] Hence the very beginnings of natural science are found among the great nations of remote antiquity—the Egyptians, Assyrians, and Babylonians.

Atmospheric phenomena must have been among the first to attract attention, and meteorology, as a branch of knowledge, is probably as old as mankind, particularly since in early times primitive man lived largely in the open, as hunter or agriculturist, and was forced to watch the weather closely for the sake of his own welfare.[5] Weather lore existed among the Chaldeans and the Babylonians two or three thousand years before the Christian era.

The first major period in the history of meteorology may be taken to be that from antiquity to about 1600 A. D. Early knowledge was cultivated only for immediate practical needs, and in very primitive times the mere observation of facts without inquiry as to causes was as far as it was carried; such knowledge does not constitute true science: We must generalize from our observations; the ultimate goal of scientific research is the discovery of fundamental and comprehensive laws, and the demonstration of how the phenomena and their laws result from a few simple underlying principles. Simple generalizations were made at an early stage by the ancients, but it was left to the Greeks to initiate abstract thought and to invent explanatory hypotheses. Greek thought culminated in the great system of Aristotle (384–322 B. C.), who gathered together and systematized all knowledge then existing, and subdivided Science, which at that time was only a part of Philosophy, into various special subjects. Aristotle's *Meteorologica* [6] was the first treatise on meteorology. Outside of the activities of the Alexandrian School, the Arabs, and the Moors, there is little to record in the history of any science during the ensuing 2,000 years of scholasticism and introspection.

Early science accepted its hypotheses without any adequate verificatory inquiry—its explanations did not have to explain more than they were directly invented to explain, and they did not have to cohere with previously acquired knowledge nor be able to predict undiscovered facts; much of this "science" was therefore quite fantastic. The *modern* trained man of science "uses his powers of observation to discover the facts of nature, his inventive ingenuity to propose various possible hypotheses for the explanation of the facts, his power of logical reflection to think out, or deduce, from each hypothesis, in accordance with previously acquired, pertinent knowledge, just what ought to happen if the hypothesis were true, and his impartial faculty of verification to decide which hypothesis, if any, is competent to explain the observed facts;" [7] and he must constantly be on his guard against the numerous errors that may creep in at any stage of the procedure. In the sixteenth century there was a general reconstruction and reorganization of thought; modern methods in science began with Galileo, and the complete Scientific Method came into prominence under the leadership of Francis Bacon (1561–1626). In philosophy, a reaction "back to nature" took place, away from the barren scholasticism of the Middle Ages; the special sciences left the philosophic fold, and became differentiated one from another; the great geographical discoveries of the fifteenth and sixteenth centuries, and the revolution in astronomy occasioned by the work of Copernicus (1473–1543) and Kepler (1571–1630), contributed to a broadening of man's mental horizon that ushered in a new area.

The second major period of meteorological history is that from 1600 to about 1800. The first essential in any

[1] Presented before the Fourteenth meeting of the Maryland-Virginia-District of Columbia Section of the Mathematical Association of America, Annapolis, Md., December 8, 1923.

[2] Wm. Spottiswoode: Presidential address before the British Association. *Rept. Brit. Assoc. Adv. Sci., Dublin, 1878.* pp. 1–32. London, 1879.

[3] See R. D. Carmichael: The provision made by mathematics for the needs of science. *Science*, (N. S.), 45, 465–474, 1917.

[4] *Cf.* R. D. Carmichael: Motives for the cultivation of mathematics. *Scientific Monthly*, 8, 160–178, 1919.

[5] See G. Hellmann. The dawn of meteorology. *Quar. Jour. Roy. Met. Soc.*, 34, 221–232, 1908.

[6] See E. W. Webster: The works of Aristotle translated into English: *Meteorologica*. Oxford, 1923.

[7] W. M. Davis: The reasonableness of science. *Scientific Monthly*, 15, 193–214, 1922.

natural science is to gather data by actual observation; the meagre observations of the ancients had been very crude, mostly made without the help of instruments, and much influenced by superstition and imagination. With the invention of the thermometer by Galileo in 1590, and of the barometer by Torricelli in 1643, accurate meteorological observations became possible. Many meteorological stations were established in Europe; and the major features of the general structure of the atmosphere, the heating of this atmosphere by the sun, and the distribution of winds, temperature, etc. over the globe, became well known.[8] The variable winds of the temperate zones, and in particular the storms and changes of weather, however, remained but little understood, on account of their irregularity and complexity, although in 1760 Benjamin Franklin discovered the regular travel of storms in eastern United States.[9] The physical properties of air, such as mass, weight, pressure, resistance, inertia, density, viscosity, expansion with heat, etc., were elucidated in the sixteenth and seventeenth centuries, and the chemical nature of the atmosphere discovered near the close of the eighteenth century.

Throughout this period, meteorology was in its early infancy, an almost purely observational and empirical science, greatly lacking in helpful theories. Only after much labor does law become apparent in the investigation of natural phenomena, particularly when these phenomena are as complex as those of our atmosphere. However, we can not doubt that the processes of weather are simply examples of the operation of ordinary physical laws, although special methods may be required for the treatment of the special problems involved. Meteorology proper (i. e., exclusive of the mere description of weather, climates, and atmospheric phenomena [10]) is essentially the *physics of the earth's atmosphere*,[11] and fundamentally it is the *mechanics of* the atmosphere, this term being taken to embrace both dynamics and thermodynamics; all other aspects are of minor importance. In addition to the meteorological information which had been accumulated up to the time we are now considering, there was a not inconsiderable knowledge of physics, but no one perceived the relationship between meteorological phenomena and physical laws, and dared to combine them, until Halley in 1686 and Hadley in 1735 [12] attempted to explain the cause of the trade winds; the latter gave an essentially correct explanation, although it needs revision from the dynamical point of view.[13] By a similar process, Astronomy at one stroke became an exact science, but meteorology took only one short step in this direction; the transformation in the case of the latter could not really begin in earnest until after extensive further advances in both observational meteorology and theoretical physics.

Analytical mechanics was brought to a high degree of perfection during the eighteenth century through the labors of Euler, Lagrange, Poisson, and Laplace. The third major period in the history of meteorology extended from 1800 to about 1850, and was particularly marked by numerous efforts to give logical explanations, largely *qualitative*, for the observed facts. Meteorological observations were increasing in number and in accuracy, and during this period notable progress was made by Brandes, Dove, Redfield, Reid, and Espy in the elucidation of the phenomena of storms.

Deep insight into the phenomena of the atmosphere began to come, however, only when meteorology, having attained vigorous youth, began to be transformed into an exact science; this transformation is still very far indeed from having been completed, but great advances have been made since the middle of the last century. There are two sides to the study of the atmosphere, which can be pursued by different people who may never meet each other: One is the observation and collection of facts, the other is the interpretation of the facts by physical and mathematical reasoning. The science of meteorology "includes the process of observing, of the first part; the compilation and summarizing, in maps or otherwise, of the facts of weather, of the second part; the application of meteorological principles, which includes the forecasting of future weather, of the third part; and the development of the science of meteorology, of the fourth part. Any one of the first three may be pursued according to recognized canons of procedure with satisfactory results; every one of them is indispensable, and all three of them may be pursued simultaneously without any effective recognition of the fourth part, which forms our only avenue to the comprehension of the secrets of the sequence of weather." [14] The mathematicians and mathematical physicists of the eighteenth century had made available for application many powerful tools, and since then further striking advances have been, and are being, rapidly made in these subjects; but in the present position of meteorology there still exist to some extent two undesirable extremes of opinion—one, to think the penetration into the secrets of the subject to be so difficult that we must be content to forego the attempt and deal with what we have; the other, to think it so easy that only observations are required, and the training of our brains of no account. However, as Sir Napier Shaw has emphasized, nothing useful can be done without real facts—brains without observations are of no avail in any problem dealing with Nature—but real facts do not, as a rule, explain themselves—observations, however numerous and excellent, will not exonerate us from the use of highly trained intelligence.

Dynamical meteorology deals essentially with the study of the behavior of a permanent gas, surrounding a rotating globe, and exposed to solar radiation, dilatable with heat and compressible with pressure, but mixed with small and variable percentages of vapors that condense to liquids or solids at ordinary low temperatures. The state of the atmosphere at any point at any instant is completely determined, so far as all weather phenomena are concerned, by the values at the time and place of the six meteorological elements—temperature, pressure, wind velocity, humidity, cloudiness, and precipitation occurring. The day-to-day fluctuations of these elements constitute weather, whereas the "normal" values at any locality, obtained by averaging a long series of observations, determine, in part, the climate. The problem before meteorology is: Given complete observations describing the state of an extensive three-dimensional portion of the atmosphere, to determine, from the laws of physics, the conditions that will result at some given time in the future. We can not rest content, nor can meteorology become most effective in a practical way, until an *exact* and *com-*

[8] See Edgar W. Woolard: Historical note on charts of the distribution of temperature, pressure, and winds over the surface of the earth. *Monthly Weather Review*, 48, 408–411, 1920. Also, Edmund Halley: On the height of the mercury in the barometer at different elevations above the surface of the earth, *Phil. Trans.*, 16, 104, 1686; and On the proportional heat of the sun in all latitudes, *Phil. Trans.*, 17, 878, 1693.

[9] Benjamin Franklin: On the northeast storms in North America. *Works*, II, pp 63–66.

[10] The standard works on descriptive meteorology are: Julius von Hann. *Lehrbuch der Meteorologie*. 3te aufl., Leipzig, 1915. (A new edition is now appearing.) And Julius von Hann, *Handbuch der Klimatologie*. 3te aufl., Stuttgart, 1908–1911. 3 vols.

[11] The only comprehensive work treating meteorology from the physical standpoint is W. J. Humphreys' *Physics of the Air*, Philadelphia, 1920.

[12] Edmund Halley: An historical account of the trade-winds and monsoons. *Phil. Trans.*, 16, 153–168, 1686. George Hadley: Concerning the cause of the general trade-winds. *Phil. Trans.*, 39, 58–62, 1735.

[13] See Sir Napier Shaw: *The Air and its Ways*, p. 53, Cambridge Press, 1923.

[14] Sir Napier Shaw: The outlook of meteorological science. *Monthly Weather Review*, 48, 34–37, 1920.

plete solution of this problem has been attained; such a solution would involve the reduction of meteorology to a mathematical science. *The progress of exact science must always wait on the progress of pure mathematics; and no science can come to even a relatively advanced state of development or perfection until it has been made to rest on a mathematical foundation and has taken on a mathematical form.* Unfortunately, at the present time the subjects of pure mathematics and mathematical physics have not been developed to an extent sufficient to handle completely the actual problems of nature involved in the study of the atmosphere, and weather forecasting as conducted by the chief meteorological services of the world has of necessity been completely *empirical*.

However, there is no justification for insisting that this shall always be the case. Meteorology has in the past gone through the various stages of development common to all the sciences and may be expected in the future to emulate those sciences which are at present ahead of it. In its infancy a science is not able to stand the strong meat of mathematics; and mathematical ideas initially find an application in it by slow processes, although even in the preliminary stages mathematics makes an essential contribution in that it furnishes the only language in which exact information can be expressed in a form such that the mind can readily grasp the import of the data, viz., through elementary statistical methods. Political science, economics, biology, psychology, and geology are now at this stage of development. In the period of vigorous youth, where chemistry may be said to be, a science is not reduced to a mathematical form, yet its laws are so stated as to be subject to the sharpest experimental verification, and it often employs the elements of the differential calculus. The most mature sciences are those which make the most extensive use of mathematics; physics is perhaps the most mature natural science at present, and the one whose recent progress has been the most rapid and whose practical applications the most remarkable; it continually taxes to the utmost the resources of pure mathematics.[15]

The elucidation of the reason for the fundamental and powerful role which pure mathematics plays in physical science forms a fascinating and extensive philosophical inquiry. One aspect of the matter is, however, apparent upon a little thought: Mathematics is the only language adequate for use in a science which is to attain to the standard of exactness and perfection which, in order to yield the maximum practical usefulness and mental satisfaction, every science strives to attain. Language of some kind is a condition of all progress in knowledge beyond the merest rudiments—the mind can not go far without a coherent system of symbols for the representation of its concepts and constructs, and as an aid to reason. Language introduces immense economy of mental effort; it enables communication between individuals; it is a fundamental element in accumulating and retaining the heritage of the past. The ordinary language of daily life, however, while adequate for the purposes which it is designed to serve, has many shortcomings and defects which render it completely inadequate for use where precise and rigorous thinking in intricate and abstract matters is involved; and what the language of daily life does for the thought of usual intercourse the language of mathematics does for exact scientific thought. Mathematics furnishes the essential means for the expression of the latter; aside from its rigorous logic, its certainty, and its universality, mathematics owes its superior power to its symbolic language, the most powerful language known, which enables it to completely outstrip every other science and every other method of reasoning; it supplies the support without which the mind would be unable to carry through the processes necessary to attain the desired results. "There is a certain storing, as it were, of intellectual force in the mathematical symbols, from which it can be released with almost explosive power. These become mighty engines through the aid of which we can rear intellectual structures quite inaccessible to our unsupported power" or to the power of ordinary language.[16] Theoretically, the use of mathematical symbols is an irrelevant convenience only; the content of any mathematical expression could be translated into ordinary language, but the result would be so lengthy, involved, and cumbersome that no meaning could be seen in it and no deductions performed upon it.

Although there is probably nothing which more directly concerns each and every person than the weather, and there are few things of more vital importance to many lines of activity than a knowledge of its future course, meteorology has been a comparatively neglected science, especially on its physical and mathematical side. It is rarely taught in any adequate or extensive way at universities; comparatively few people have even an elementary knowledge of the subject; it has not been endowed with great observatories and institutions to the extent that astronomy has; and it has not attracted the attention of a very great number of able physicists and mathematicians. Furthermore, practical meteorologists do not always look with favor upon the attempts of the mathematical physicists to advance the science of meteorology; but it must be recognized that behind every high art there stands a higher science, that complete success in weather forecasting demands an equally complete knowledge of the sciences involved in the motions of the atmosphere, and that satisfactory progress in the improvement of daily predictions can only be based on corresponding progress in our knowledge of theoretical meteorology obtained with the help of the best mathematicians and physicists.[17] The method of forecasting by empirical rules and past experience is only a stage in our advance; it leads, as we know, to excellent and valuable results in the hands of the experienced, but its capacity is limited and the limit is very soon reached. To improve it, to carry it further, or to make out the true inwardness of its application in special cases, we must, as Shaw, Abbe, and others have insisted, depend on advancing our knowledge of the dynamics and physics of the atmosphere. It would be utterly absurd at the present time to entertain seriously the idea of forecasting weather, now or probably for many generations to come, by mathematical equations as the movements of the heavenly bodies are forecast; nevertheless we are even now introducing *scientific* considerations into the making of forecasts, and every small advance in our understanding of atmospheric phenomena will, sooner or later, be found to be of practical use in improving predictions, and will contribute in some measure toward making forecasting less of an empirical art and more of an exact science, whether or not we are ever enabled to reach or even remotely approach the ultimate ideal goal of exact mathematical calculation of the coming weather. Those who are impatient with mathematical studies on the atmosphere ask, "How can this be of any use? The

[15] Carmichael, *l. c.*

[16] R. D. Carmichael: The larger human worth of mathematics. *Scientific Monthly* 14, 447–468, 1922. Also, E. D. Roe, jr.: A survey of mathematics and astronomy, *ibid.*, 17, 248, 1923.

[17] See Cleveland Abbe: The progress of science as illustrated by the development of meteorology. *Ann. Rept. of the Smithsonian Institution for 1907*, pp. 287–309. Washington, 1908.

calculations must require a preposteriously long time. Under the most favorable conditions it will take the learned gentlemen perhaps three months to calculate the weather that Nature will bring about in three hours. What satisfaction is there in being able to calculate tomorrow's weather if it takes us a year to do it?" Bjerknes has answered quite clearly: "If only the calculation shall agree with the facts, the scientific victory will be won. Meteorology would then have become an exact science, a true physics of the atmosphere. When that point is reached, *then* the practical results will soon develop. It may require years to bore a tunnel through a mountain. Many a laborer may not live to see the cut finished. Nevertheless this will not prevent later comers from riding through the tunnel at express train speed."[18]

The fourth and present period of meteorological history opens with the first attempts at constructing mathematical theories of the phenomena of the earth's atmosphere, beginning with the remarkable pioneer work of the American William Ferrel,[19] which gave a strong impulse to similar theoretical research by Helmholtz, Guldberg and Mohn, Hertz, von Bezold, Oberbeck, Sprung, Margules, and others. Most of this literature has been collected and translated into English by Abbe,[20] and in addition we have a comparative study of the different theories by Bigelow,[21] and an excellent textbook by Exner.[22] Shortly after 1850 the various governments began establishing weather bureaus, synoptic charts were prepared, and with the advent of the telegraph weather forecasting was initiated; in the latter part of the century the exploration of the upper air by kites and sounding balloons began, and in recent years has increased greatly, especially through the use of the pilot balloon. Much of the observational information upon which the construction of theories must rest has been gathered together by Hildebrandsson and Teisserenc de Bort,[23] but meteorologists are still greatly handicapped by the lack of adequate observational information. Whether one is studying meteorology from the standpoint of practical day-to-day forecasting (by whatever method) or from the standpoint of the mathematical theory of meteorological phenomena, satisfactory progress can not result until we have daily synoptic charts and aerological data covering in detail at least an entire hemisphere. Meteorology is peculiarly insatiable among the sciences in its demands for data. In recent years, much has been done toward making possible a fairly satisfactory daily surface synoptic chart for a large part of both the land and water of the Northern Hemisphere, but information concerning the upper air still remains extremely fragmentary.

In order to make our problem tractable at all, particularly at the start, simplifying assumptions have to be made—the natural reality must be replaced by a reasonable, workable ideal. Much of the work just mentioned deals with more or less *ideal* cases,[24] in some of which assumptions are introduced which carry us right away from actual conditions into hypothetical states which never exist, and in others of which there is considered only one of the great fundamental factors operating. We must, in order to reach a complete and satisfactory solution, simultaneously consider the actual conditions existing in the atmosphere under the influence of all the great factors—the rotation of the earth, the gravitational field, the distribution of temperature, friction and viscosity, the condensation and evaporation of moisture, thermodynamics of ascending and descending air, radiation and absorption, etc.—as expressed in one systematic set of mathematical equations. Needless to say, this calls for mathematical ability of a high order. At the present time there are several mathematicians and physicists who are working at the foundations of weather forecasting along strictly scientific lines, and are conducting important researches in theoretical meteorology, more and more along the lines of treating the *actual* conditions of nature by mathematico-physical methods.

Investigations are being conducted in a particularly exemplary manner by the Norwegian meteorologists under the leadership of V. Bjerknes: (1) In the first place, the Bergen meteorologists have, with an extremely close network of observing stations, brought to light details not known before, and have sought to show that their synoptic maps can be simulated by wave motion on either side of a surface of discontinuity which separates a cap of polar air from the warm equatorial air. The successive cyclones of the temperate zones are Helmholtz waves on this boundary surface, and the corresponding boundary line—the "polar front"—at the ground traverses the centers of depressions all around the polar region; the examination of depressions individually from their formation to their disappearance shows that young cyclones correspond to slight waves with small excursions from the equilibrium state; later the amplitudes increase simultaneously with a deepening of the depression. The life cycle of a cyclone has been worked out in great detail from actual observations interpreted in the light of this theory; the Norwegian weather maps are now drawn in accordance with the principles of the theory, and forecasts made accordingly. Marked success has attended the Norwegian methods of scientific forecasting. The germs of the polar front theory are contained in the work of Dove, and many of Bjerknes's ideas are an extension of those of Helmholtz, Brillouin, and Margules; similar ideas have been arrived at empirically by Humphreys and by Shaw; but never before has the theory been so elaborately developed and scientifically applied to daily forecasting. The generalizations established for Norway have not been tested in other regions of the world to any extent, however, because of the lack of sufficiently detailed data; the theory itself has been criticised from both the observational and the theoretical standpoints, and can not be regarded as final and proved, particularly as regards the details of the structure of cyclones in other countries than Norway.[25] (2) Then, in the second place, these meteorologists have at the same time, as a matter of *research*, tried to work out the course of the weather in a certain limited region by mathematical calculations based directly on physical laws applied to meteorological data as complete as obtainable, mainly by employing graphical methods to solve the differential equations involved.[26]

[18] See V. Bjerknes: Meteorology as an exact science. *Monthly Weather Review*, 42, 11–14, 1914.

[19] Wm. Ferrel: The motions of fluids and solids on the earth's surface. *Prof. Papers of the Signal Service*, No. VIII. Washington, 1882. Meteorological researches for the use of the Coast Pilot, *Rept. Supt. U. S. Coast Survey*, 1875, 1878, and 1881. Recent advances in meteorology, *Rept. Chief Signal Officer for 1885*, App. 71, Washington, 1886. *A popular treatise on the winds*, New York, 1889.

[20] Short memoirs on meteorological subjects. *Ann. Rept. Smith. Inst. for 1877*, pp. 376-478. Washington, 1878. The mechanics of the earth's atmosphere, second collection, *Smith. Misc. Coll. 843*, Washington, 1891; third collection, *Smith. Misc. Coll.*, vol. 51, No. 4, Washington, 1910. See also Marcel Brillouin: *Mémoires originaux sur la circulation générale de l'atmosphère*, Paris, 1900.

[21] F. H. Bigelow: Report on the international cloud observations. *Rept. of the Chief of the Weather Bureau for 1898–99*, vol. II. Washington, 1900.

[22] F. M. Exner. *Dynamische Meteorologie*. Leipzig, 1917.

[23] Hildebrand Hildebrandsson and L. Teisserenc de Bort: *Les bases de la météorologie dynamique*. Paris, 1898–1905. 2 vols. See also the British *Réseau Mondial*.

[24] Of this nature are the very recent kinematical studies of T. Kobayasi, "On the mechanism of cyclones and anticyclones," *Quar. Jour. Roy. Met. Soc.*, 49, 177–189, 1923; and V. H. Ryd, "Travelling cyclones," *Pub. fra det Danske Meteorologiske Institut, Meddelelser Nr. 5*, Kjöbenhavn, 1923.

[25] See J. Bjerknes; On the structure of moving cyclones, MONTHLY WEATHER REVIEW, 47, 95–99, 1919; V Bjerknes: The meteorology of the temperate zone and the general atmospheric circulation, *Nature*, 105; 522–524, 1920; J. Bjerknes and H. Solberg: Life cycle of cyclones and the polar front theory of atmospheric circulation, *Geofysiske Publikationer*, Vol. III, No. 1, Kristiania, 1922.

[26] V. Bjerknes, *et al:* Dynamic meteorology and hydrography. 2 vols. *Carnegie Institution of Washington, Pub. 88.* Washington, 1910–1911.

In the system of fundamental partial differential equations expressing the state of the atmosphere, there are four independent variables—time, elevation above mean sea level, latitude, and longitude—and seven dependent variables—the three components of wind velocity, pressure, temperature, density, and joint mass of solid, liquid, and gaseous water per mass of atmosphere. The equations are the three hydrodynamical equations of motion of a fluid covering a rotating globe, the equation of continuity, the characteristic equation of state for gases, and two thermodynamical equations relating to the conveyance of heat and water.[27]

Special difficulties are at once encountered in connection with the hydrodynamical equations.[28] In the first place, classical hydrodynamics assumes the density to be a function of the pressure only,[29] whereas in the atmosphere many other independent variables, such as temperature and humidity, affect the density. The hydrodynamics of *baroclinic* fluids, i. e., fluids in which the density is a function of other variables besides the pressure—has been worked out by Bjerknes, but strangely enough has been incorporated in only one treatise on hydrodynamics.[30] In such fluids surfaces of equal density are not always surfaces of equal pressure and the formation and annihilation of vortices are possible.[31] In the second place, the resistance of the surface of the earth and the disturbances caused by the irregularities thereof give rise to a very turbulent condition of the lower atmosphere, the effect of which must be taken into account. The ordinary viscosity of the air is so small that it may be neglected, but the effect of turbulence is to give the air a virtual or pseudo viscosity many thousand times greater than the ordinary viscosity.[32] This turbulence is an extremely important factor in the transmission of heat and water vapor through the atmosphere.

The only forces acting on any mass of air are gravity, hydrostatic pressure, and friction; the acceleration of the mass is composed of two parts—acceleration relative to the surface of the earth, which is observable, and acceleration common to this surface itself; it is the acceleration of the surface which gives rise to the so-called "deflecting force of the earth's rotation." There are three cases:[33] (1) Eulerian winds, in which the rotational and frictional terms in the equations of motion are so small in comparison with the accelerational terms that they may be neglected—the observable acceleration corresponds to the horizontal pressure gradient, as in ordinary elementary hydrodynamics; (2) Geostrophic winds,[34] in which the accelerational and frictional terms are negligible in comparison with the terms arising from the rotation of the earth—the velocity is at *right angles* to the pressure gradient, giving rise to the interesting paradox that, in the Northern Hemisphere, air pushed north blows east;[35] and (3) Antitriptic winds, in which the accelerational and rotational terms are negligible in comparison with the frictional term—the wind blows in the direction of the pressure gradient, but without acceleration. Examples of these three classes are, respectively, tropical cyclones, slow-moving extratropical cyclones, land-and-sea breezes.

Eastern mathematical genius has recently made its entry into our field, in the work of Fujiwhara.[36] In ordinary fluids, vortices of the same sense of rotation have a tendency to approach, and those of opposite senses to separate, just the opposite of what happens in an ideal fluid; this may explain Okada's Law concerning the behaviour of cyclones and anticyclones. Employing a well known equation, due to Hesselberg and Friedmann, for the determination of the rate of change of the vorticity of horizontal motion in the atmosphere, Fujiwhara shows that the most important source of energy for a cyclone is in the vorticity of the surrounding air, and undertakes a new theory of the production and growth of cyclones along the polar front, in which a number of known facts come together in harmony.

The most thoroughgoing and comprehensive attempt to reduce the treatment of the phenomena of the atmosphere, as actually presented to us in Nature, to a systematic branch of mathematical physics is that of the British physicist L. F. Richardson.[37] In his study, practically every physical and dynamical process in the atmosphere is analyzed in detail, all meteorological phenomena are coordinated into a systematic whole and expressed by a set of equations which aid greatly in obtaining an insight into how the meteorological elements act and react on each other. Whatever direction practical forecasting may take in the future, Richardson's work can not fail to be of great practical benefit, aside from its purely scientific interest and importance.

At present it is perhaps best to separate such highly theoretical investigations from any suggestion of immediate direct application to forecasting; it is extremely interesting to know, however, that Richardson obtains a solution of his set of equations by means of the calculus of Finite Differences, and applies it to the computation of coming weather, using a very complete set of surface and free-air data which happens to be available for middle Europe at 1910, May 20, 7h., G. M. T. The resulting "forecast" is rather disappointingly in error, however, particularly in respect to the pressure changes, because, apparently, of inaccuracies in the observational data; and of course the calculations are so prohibitively laborious as to preclude the possibility of ever actually making forecasts in this way; besides, much of the really interesting detail in the weather is "smoothed out" by the method of solution.

An adequate comprehensive treatise on dynamical meteorology, for the reader with extensive mathematical training, has not yet been written, although greatly needed. The advancement of meteorology from this standpoint will long offer a fertile field for research by the mathematical physicist, and it is desirable that as many as possible be attracted to it. Purely mathematical difficulties, no matter how great, must eventually be overcome, for the Philosophy of Mathematics teaches us[38] that the power of pure mathematics is unlimited—its advance can not be stayed—because it meets difficulties by a creative act of the mind which leaps over them.

[27] See Bjerknes; MONTHLY WEATHER REVIEW, 42, 11–14, 1914; Abbe, The weather map on the polar projection, MONTHLY WEATHER REVIEW, 42, 36–38, 1914; and L. F. Richardson; *Weather prediction by numerical process*, chap. iv, Cambridge Press, 1922.

[28] For the derivation of these equations see: J. H. Jeans, *Dynamical theory of gases*, 3 ed., Cambridge Press, 1921, pp. 165–175; P. Appell, *Traité de mécanique rationelle*, Tome III, 3 ed., Paris, 1921; H. Lamb, *Hydrodynamics*, 4 ed., Cambridge, 1916, p. 318.

[29] Lamb, *op. cit.*, Art. 8; Appell, *op. cit.*, Art. 627.

[30] Appell, *op. cit.*, chap xxxii, pp. 562–605.

[31] See V. Bjerknes: On the dynamics of the circular vortex, with applications to the atmosphere and atmospheric vortex and wave motions. *Geopysiske Publikationer*, Vol. II, No. 4, Kristiania, 1921.

[32] See G. I. Taylor: Eddy motion in the atmosphere, *Phil. Trans.*, A215, 1–26, 1914, and later papers cited in the bibliography on p. 92 of Richardson, *op. cit.*

[33] Harold Jeffreys: On the dynamics of wind. *Quar. Jour. Roy. Met. Soc.*, 48, 29–47' 1922.

[34] Sir Napier Shaw: *Manual of meteorology*: Part IV, The Relation of the wind to the distribution of barometric pressure. Cambridge Press, 1919.

[35] W. J. Humphreys: *Weather proverbs and paradoxes*, p. 88. Baltimore, 1923.

[36] S. Fujiwhara: On the growth and decay of vortical systems and the mechanism of extratropical cyclones. *Bull. Central Met. Obs. of Japan*, 3, 151–208, 1923.

[37] L. F. Richardson. *Weather prediction by numerical process*. Cambridge Press, 1922.

[38] See J. B. Shaw. *Lectures on the philosophy of mathematics*. Chicago, 1918.

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USING WEATHER RECORDS.[1]

By J. CECIL ALTER, Meteorologist.

[U. S. Weather Bureau, Salt Lake City, Utah, Sept. 19, 1923.]

The daily temperature and precipitation records at the four or five thousand cooperative weather stations in the United States, and the continuous, automatic records for all the principal meteorological elements at the 200 regular Weather Bureau stations, form a great potential asset, available free to the public. The weather forecasts are read and utilized daily and universally as is no other information, and the value of this intelligence is incalculable. But there is often an equal value, and in many circumstances a far greater value, to be found in the records of what the weather has been.

The weather is a liability only when one attempts to ignore it or to rely on an erroneous belief or a vague weather lore. But it is an asset of inestimable worth when the facts of record are properly applied to business and personal problems. A long weather record, like money, is of no active value unless used. The Weather Bureau aims to maintain weather stations where the product will be of greatest use, and it aims to observe such elements and to record and publish the data in such a manner as to meet the most general need. It is a fact, however, that in establishing the climatic facts of the country as required by law, the bureau has necessarily produced weather records of great value for other purposes far in excess of their general utilization. Consequently a frozen asset of large proportions and of much promise has already been accumulated.

Business enterprises, like the people themselves, live, move, and have their being in the weather to a far greater extent than is commonly supposed. There are in fact comparatively few occupations or businesses that can not be conducted with a little more refinement and certainty, a little less trouble and mistake making, and with an important saving or actual earning of money, by a more frequent use of weather records.

The risk assumed of a killing frost, stormy weather, hail, drought, high wind, or lightning, is a legitimate charge against many businesses; and insurance companies are doing a profitable and worthy business writing weather insurance, basing the premium rates on the weather records. Business men and organizations themselves very often reduce their weather risks by altering their plans or dates to fit better into the weather averages.

A Utah umbrella dealer, who is credited with having made the dollar famous locally, had always ordered deliveries in bulk during the autumn; but on seeing a diagram of normal precipitation by months, ordered deliveries thereafter on the first of each month proportional to the number of inches of normal precipitation. Having a 30-day arrangement for remittances, he has since usually transacted business on the manufacturer's capital, has had a better opportunity to store his surplus stock and to follow styles, and has filled in the dry summer months with parasols. Through a period of years the climate can usually be foreseen in a general way if the specific weather can not. The umbrella season is no better defined in the country's weather records than are the fur clothing, house painting, or countless other seasons.

A Utah sheep breeder was ready to send a flock of rams to the range herds, but, having previously suffered losses at lambing time, inquired for weather conditions on his range 144 days from the date of the arrival of the rams. The weather could not be predicted that far in advance; but curves showing mean daily minimum temperatures and latest spring killing frosts indicated a period of relative safety beginning shortly after May 20. His previous losses had occurred when the lambs were dated prior to May 15, as had been warranted on another range. Since that inquiry, two successful seasons have followed in those herds, the lambs being brought in late May or early June, as suggested by the weather records.

A new and promising commercial enterprise is rising on Great Salt Lake, largely, through the reassurance contained in a weather record. Sodium sulphate is surrendered in large quantities when the water temperature is below 32°. A group of chemists and capitalists, having the occurrence under observation, noted specific dates and periods when the sulphate cast up on a certain beach could have been gathered profitably before it was redissolved by wave action. A 20-year weather record at Saltair Beach pavilion supplied the answer to the all-important question: How long do such conditions obtain and how frequently do they occur?

Assured of an average producing season of about two months each winter, a $25,000 harvesting, desiccating, and refining plant was established last autumn and much additional equipment is being installed this season. The company is prepared, however, as admonished by the weather records, to remain idle in an occasional winter and to care for a three or four months' crop in others.

The weather records often serve as detectives, of an impersonal and unimpeachable sort. A smelting company, purchasing coke from a producer 150 miles distant, observed a persistent shortage and after several years filed a claim with the railroad for about $11,000. The railroad company had reason to believe no coke was lost en route, and a graph of the losses by months showed a striking relationship with weather conditions; that is, the loss was almost nothing from October to March, the season of most numerous storms and highest humidity, some winter shipments having showed a gain, while during the remaining months, or the dry season, of increased winds, the loss ranged from 2,000 to 3,000 pounds per car. Further inquiry developed the fact that the coke was quenched with a heavy spray of water while passing from the ovens to the cars, in which it was weighed. Plainly it was a loss of moisture and not of coke, and the problem resolved itself into an adjustment of weights instead of a claim for losses, the coke company becoming the defendant.

A specializing nut-tree grower, seeking a habitat for pecans in Utah, has applied mean monthly temperatures very successfully to the problem in a scheme or diagram of so-called "pecan units." From an extensive examination and analysis of temperatures, frost, and precipitation in sections where pecans are grown successfully, it was determined that the total number of degrees of mean monthly temperature in excess of 50° formed a basis for rather accurately allocating pecan trees of different varieties; that is, the northern pecan flourishes on a commercial scale in a climate having a total of from 135 to 145 "pecan heat growing units," or mean temperature degrees in excess of 50 for each growing month. The southern pecan requires about 175 pecan units, while the

[1] Presented before American Meteorological Society, Los Angeles, Calif., Sept. 17-19, 1923.

primitive southern pecan from which other varities were propagated requires about 220 units. The inescapable conclusion was that certain Utah sections will grow pecans profitably, and an important acreage is accordingly being planted.

About 50 families of emigrants, having a common language and social experience, moved into what was supposed to be a dry farming section without properly considering the weather records. That district became prominent during the next few years, when the emigrants failed to get crops for want of rain and were forced to move at a great loss.

The colonization agent for a large religious organization was offered an irrigation project, supposedly worth $100,000 at basic land prices, for the sum of $18,000, which the company had already invested in improvements. The company expected to make the project worth a million dollars, but failed to finance it for a very good reason. The weather records, which they had overlooked, contained the answer, and the colonization agent turned the offer down. The summers are so short and the nights so cool as to threaten even barley and flax as regular crops.

A farmer with a weather slant owns a hill of moulding sand, which he loads onto freight cars at convenient times and sells to certain Utah foundries. A purchaser docked him 50 per cent on a car received during a prolonged spell of wet weather; but the farmer produced the official weather record and calculated the exact weight of moisture added by the precipitation and saved himself something near $50.

A consignment of Utah wool reached destination damaged by moisture to the extent of $7,000. The railroad company was asked to settle, but resisted the claim because there had been no rain at any transfer point and the car roofs were good. A number of substation weather records showed heavy rains in the district about the isolated shearing corral during the time the wool awaited transportation to the railroad.

The same company did not hesitate, however, to pay $80 for a trunk of clothing that got wet in an official rainstorm at the railroad station whence a college girl departed on a vacation. Neither did it demur at canceling a demurrage charge on a string of empties set on a siding in a Utah grain section during rainy weather. The farmers could not deliver the grain because of muddy roads, a condition beyond their control.

Speaking of muddy roads, a motorcyclist collided with a work team and farm wagon in broad daylight on an unpaved Utah roadway. He very narrowly escaped the final summons, and repined in the State mental hospital for some months because of an aberration resulting from the accident. But he subsequently knew enough to enter the courts armed with weather records to prove that heavy rains prior to the collision had muddied the road, which became deeply rutted, preventing his turning aside for the team. Being in the right-hand path it was decided that he had a legal right to expect the teamster to yield. The teamster's memory was that the road was smooth.

A sheep man of many parts in his own business once pulled the wool over his own eyes by assuming he had discovered that a rainy summer in the Rocky Mountains, which produced much grass and many fat sheep, was also a summer of comparative drought in the corn States, resulting in low yields and high corn prices. He also reasoned that a dry season in the mountains would be a fine time to pick up feeder stock to be finished on an abundance of low-priced corn. After a couple of expensive surprises he visited the Weather Bureau office and learned, what any meteorologist could have told him before he bought the feeder stock, that such weather relationships were purely accidental.

A mining company developed a goodly stream of water in its underground workings, and, simultaneously a mountain stream near by, used for irrigation, failed appreciably. The miners sought to retain ownership to the water and to establish the fact that dry weather had caused the irrigation stream to dwindle.

One of the most extensive, expensive, and bitterly contested series of water lawsuits in Utah finally grew out of this and another similar case; even distant hydroelectric companies, the Salt Lake City corporation, the State of Utah, and the United States Government taking a so-called friendly hand because of the dangerous precedent that might be established in a decision. The controversy, not yet settled, revolves to a large extent around precipitation records. Was the tunnel flow developed at the expense of the natural stream discharge or are these phenomena masked by a fluctuating precipitation?

In comparatively recent months we have been requested to determine the average and extreme weights of snow per unit area on the roof of a proposed amusement hall down State, a marble kiosk or covering for a statuette, and a warehouse and salesroom in Salt Lake City, as well as six or seven cottages and a club house at mountain summer resorts, where heavy snow is usual. In every case the architect's plans were either drawn with the snow weight figures at hand or the plans were altered subsequently to provide for the calculated maximum strain.

Snow sags heavily when allowed to accumulate, as a railroad company discovered when a band of sheep, being moved to spring pastures, were weighed in with about 4 inches of snow on their backs, and the loss of weight had to be accounted for at destination. Utah lumbermen purchase Oregon spruce and fir, and they sometimes pay freight on Oregon snow and Oregon moisture in the materials, which moisture they are deprived of en route by the dry climates of Idaho and Utah. But the sorest man, perhaps, is the speed fiend in court who blames snow on the wind shield for a collision and is confronted with a weather record establishing an alibi for the storm.

The wind, which accomodatingly comes in at the kitchen window on a summer morning and into the library or across the front porch on a summer evening, when the residence architect has given due consideration to orientation factors in certain locations, becomes a veritable demon when it topples a brick wall or a bill board onto a pedestrian. And, demon though it is, it is designated an "act of God" in law if the wind was hanging up a record run. This circumstance opens the way to a fertile field of excuses; but one wall, well known in our office, could not withstand a trumpet blast. It went up in the afternoon and down at night; and in the lack of a justifiable windstorm, cross-examiners developed some embarrassing facts about the manner of the wall's construction.

The automobile is a modern machine for making wind, as is well known from the joys of ownership to nearly everyone but weather men. But the weather men, who figuratively ride the wings of the wind all day and then walk home at night, have sometimes earned automobiles

for others. A certain new limousine in the hands of an equally new driver overturned on the highway, and the insurance company was asked to exchange the purchase price for the wreck because of a high wind.

The Weather Bureau gained a friend in the insurance adjuster and a new acquaintance in the automobile owner by showing that the highest wind record in the State would have exerted but one-half the pressure against the side of the car that it was admitted to have carried on its tires.

To enumerate or even indicate the avenues into which the records in the custody of the Weather Bureau may flow continually or occasionally would be as great a task as to list the places visited by the wind, or shone upon by the sun, or wet by summer showers, or draped by winter snows. It should suffice merely to indicate that this impersonal and impartial arm of the Government is always ready, and usually competent, to lift some individual or business over a hard place and to steady the scales of justice within and outside of the public courts.

THE WEATHER OF 1923.

By ALFRED J. HENRY.

Precipitation.—Continental United States as a single geographic unit received slightly more than the average precipitation, area alone considered. See the chart of annual deviation from the normal. The districts having a pronounced deficit are the Pacific Coast States, including Idaho, the Lake region and Atlantic Coast States, including the Florida Peninsula. More than the normal precipitation was recorded in the great grazing areas of the West, including the Plains States; also in the Gulf States, Tennessee, and the Ohio Valley. Numerical values of the monthly and annual deviation are given in Table No. 1. Computing the mean deviation for the United States as a whole the result comes out a negative quantity—2.2 inches. This is explained as due to the magnitude of the deviation in two small districts—Florida Peninsula on the Atlantic (−17.8 inches) and the Middle Pacific coast (13.6 inches).

The outstanding feature of the year as regards precipitation is the heavy rains in the Arkansas Valley in southeastern Kansas in June and in Oklahoma and adjoining States in September and October. Destructive floods occurred in both southeastern Kansas and in Oklahoma.

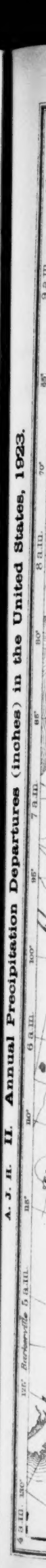
TABLE 1.—*Precipitation departures, 1923.*

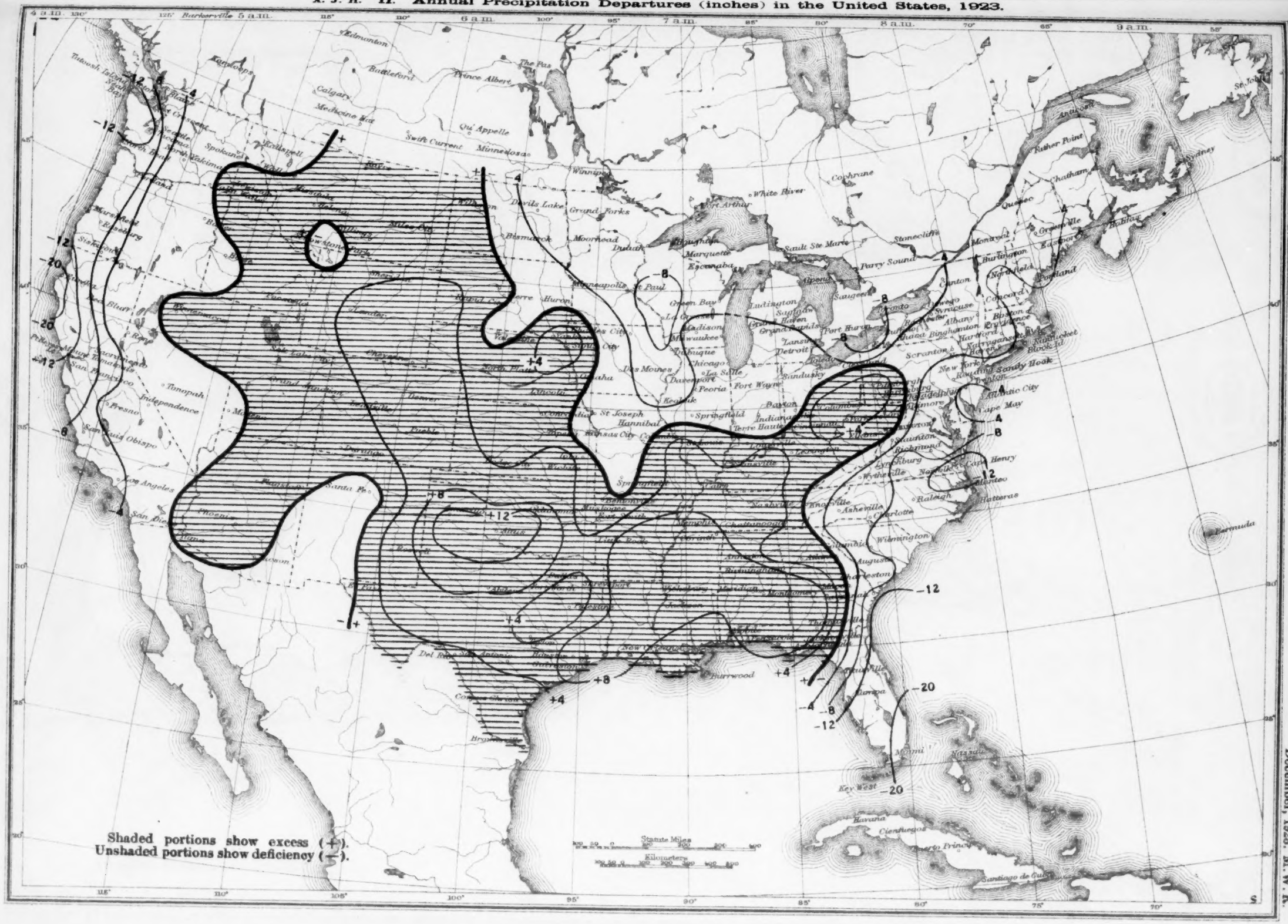
Sections.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Accumulated departure.
New England	+2.1	−1.8	−0.5	+1.4	−1.9	−0.4	−0.6	−2.0	−1.2	+0.3	−0.1	+0.7	−4.0
Middle Atlantic States	+0.6	−0.8	+0.3	+0.1	−1.5	−1.3	−0.2	−1.6	+0.4	−0.7	−0.6	−0.1	−5.4
South Atlantic States	−0.9	−1.2	−0.6	−0.8	+0.8	−1.9	+0.4	−0.9	−1.0	−1.8	−0.9	−0.4	−9.2
Florida Peninsula	−2.2	−2.3	−1.6	−0.6	+3.4	−1.7	−2.1	−1.7	−2.0	−3.6	−1.8	−1.6	−17.8
East Gulf States	−1.5	+0.8	+0.2	+1.9	+5.1	+0.9	+0.6	+0.8	−2.4	+0.5	+0.8	+0.4	+8.1
West Gulf States	+0.5	+1.4	+0.2	+0.9	−0.3	−1.1	−0.1	−0.7	+2.1	+0.4	0.0	+3.0	+6.3
Ohio Valley and Tennessee	+0.9	−0.2	+0.1	+0.4	+0.2	+0.4	−0.2	+1.0	−0.1	−1.0	−0.6	+2.4	+3.3
Lower Lake region	+0.1	−1.0	−0.3	−0.3	−0.1	−0.7	−1.4	−0.8	0.0	−0.7	−0.5	+0.8	−4.9
Upper Lake region	−0.4	−0.6	+0.4	−0.6	−1.0	−0.8	+0.3	−0.3	+0.1	−0.2	−1.4	−0.2	−4.7
North Dakota	−0.2	0.0	−0.5	−0.2	−1.2	+0.3	−0.3	−0.6	+0.7	−0.4	−0.3	−0.3	−3.0
Upper Mississippi Valley	−0.2	−0.9	+1.2	−0.8	−1.1	−0.3	−1.9	+0.8	+0.9	−0.4	−0.8	+0.1	−3.4
Missouri Valley	−0.2	−0.7	+0.2	−0.4	−1.0	+1.2	−1.0	+0.7	+2.2	+0.4	−0.3	−0.1	+1.0
Northern slope	−0.3	−0.3	−0.3	0.0	+0.1	+0.8	+0.9	+0.5	+1.1	+0.9	−0.3	−0.2	+2.9
Middle slope	−0.2	−0.4	0.0	−0.2	+0.9	+2.3	−0.6	+0.4	+1.6	+3.0	0.0	0.0	+6.8
Southern slope	+0.4	+1.1	+1.0	+1.2	−2.0	+1.5	−0.7	−1.3	+1.4	+3.8	+1.2	+0.6	+8.2
Southern Plateau	−0.5	−0.2	+0.1	+0.1	−0.1	−0.3	−0.5	0.0	0.0	+0.1	+0.4	+0.4	−0.5
Middle Plateau	+0.2	−0.7	−0.4	+0.2	−0.4	+0.4	−0.1	+0.5	+0.2	−0.1	−0.2	−0.4	−0.8
Northern Plateau	−0.1	−0.5	−0.9	+0.1	−0.4	+1.2	+0.3	+0.4	−0.4	+1.0	−0.5	−0.2	0.0
North Pacific coast region	+2.3	−1.8	−2.1	−1.2	−0.7	−1.1	+0.5	+0.4	−1.0	−1.4	−3.7	0.0	−9.8
Middle Pacific coast region	−2.0	−3.3	−3.7	+0.7	−0.9	+0.3	0.0	0.0	+0.7	−0.6	−2.1	−2.7	−13.6
South Pacific coast region	−0.6	−1.4	−2.4	+1.8	−0.6	0.0	0 0	0.0	+0.2	−0.6	−1.1	−1.3	−5.8
United States as a whole													−2.2

Temperature.—For the country as a whole the year was a warm one, thus completing a period of three consecutive warm years, in two of which the warm weather was more pronounced than in the year just closed. The latter was not characterized by periods of unduly warm or cold weather respectively, although January was uniformly warm for a winter month in all parts of the country. June was a rather warm summer month, being characterized, in the East, by a rather large number of consecutive days with high day temperature, but the two summer months immediately following were, on the whole, agreeable months, the periods of high and low temperature alternating in such a manner as to prevent long continued spells of high day temperatures.

August was unusual in respect of movement of marked anticyclones into the Missouri Valley from the Canadian Northwest and these were naturally associated with abnormally cool weather for the season.

In some quarters such a movement is held to be indicative of the early approach of cool weather; in this case, however, the promise failed to materialize, the months of November and December being unusually warm. The numerical values of the variations from normal by districts are given in Table 2 and geographically by the chart on the reverse side of the precipitation chart.





December, 1923. M. W. R.

11—185.

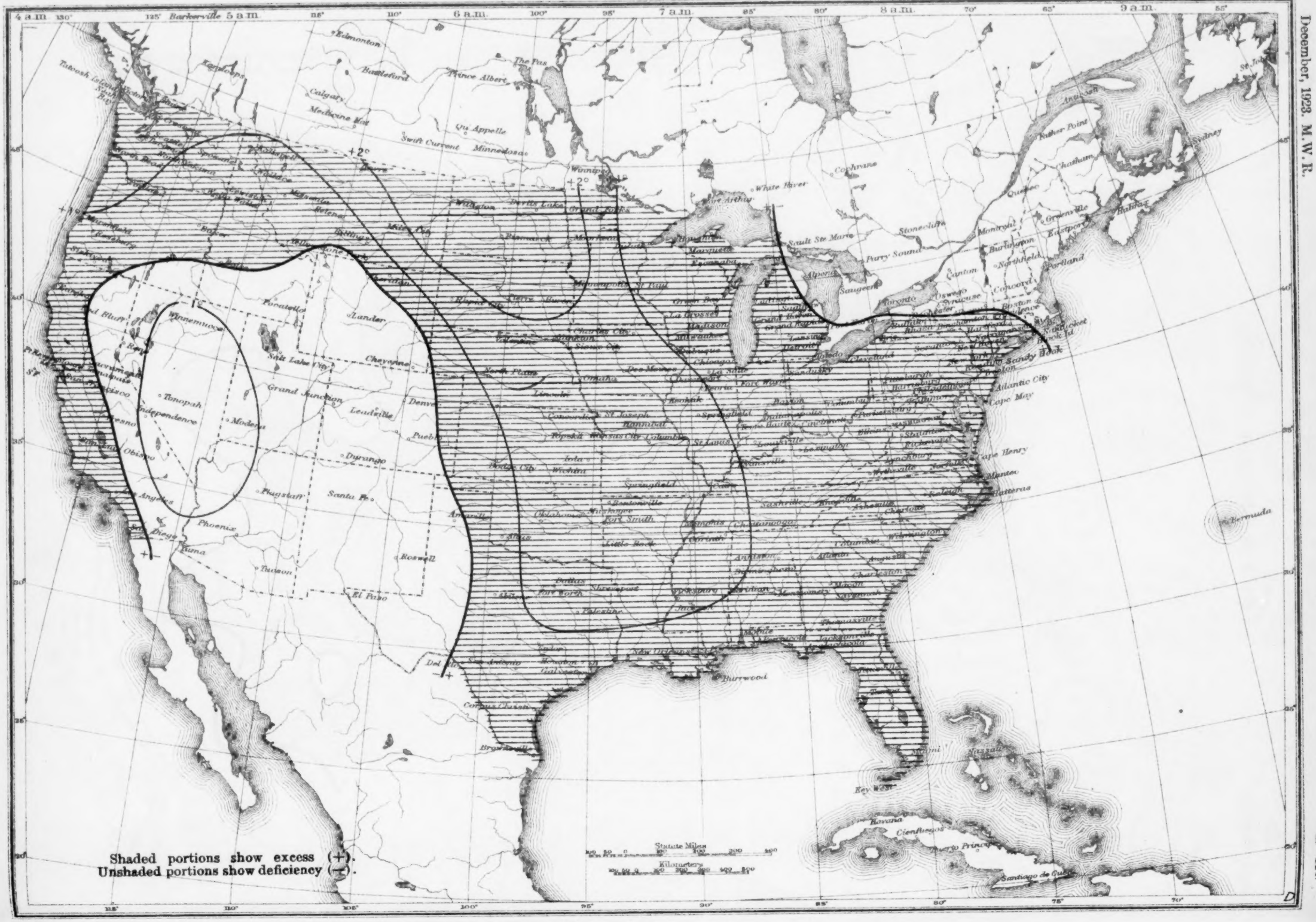

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Statute Miles
Kilometers

TABLE 2.— *Temperature departures, 1923.*

Sections.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average monthly departure.
New England	−2.1	−6.2	−3.7	−0.1	−0.9	+1.5	−2.2	−1.7	+1.1	+0.9	+1.9	+7.1	−0.4
Middle Atlantic States	+1.7	−3.4	+0.4	+0.1	−1.4	+2.7	−1.1	−0.9	+1.3	−0.9	+0.1	+8.0	+0.6
South Atlantic States	+4.0	−1.6	+2.1	−0.3	−2.2	+0.1	−1.1	+0.9	+1.7	−1.3	−2.0	+6.4	+0.6
Florida Peninsula	+1.8	+1.5	+2.8	+1.6	−1.5	−0.6	−0.7	−0.2	−0.4	−1.5	−3.2	+3.4	+0.2
East Gulf States	+6.7	−1.0	−0.5	+0.2	−2.0	−0.9	−1.9	−0.2	+2.0	−1.1	−1.7	+6.7	+0.5
West Gulf States	+10.2	−1.2	−3.3	+0.4	−0.2	+0.9	+0.3	+2.0	+0.9	−1.7	−0.6	+4.3	+1.0
Ohio Valley and Tennessee	+5.9	−3.6	−1.0	−1.0	−2.2	+0.5	−0.4	−0.3	+0.8	−1.7	+0.6	+9.0	+0.6
Lower Lake region	+0.8	−4.3	−2.2	−1.4	−3.7	+1.7	−0.8	−1.7	+0.4	−1.6	+1.2	+8.6	−0.2
Upper Lake region	+2.7	−4.9	−5.4	−1.5	−1.3	+3.1	+0.8	−2.2	+0.2	−0.6	+3.9	+8.3	+0.3
North Dakota	+5.9	−2.8	−4.3	−1.0	+1.0	+3.6	+3.6	−2.3	+2.7	+1.2	+10.6	+11.2	+2.4
Upper Mississippi Valley	+7.8	−3.5	−4.4	−1.0	−1.0	+1.9	+2.3	−0.8	−0.3	−2.9	+3.4	+9.9	+1.0
Missouri Valley	+11.1	−0.1	−2.3	+0.2	−1.3	+0.7	+2.2	−0.1	+1.5	−2.2	+5.5	+7.6	+1.9
Northern slope	+7.8	−3.1	−1.2	−0.9	0.0	0.0	+3.0	−0.9	+1.0	−2.5	+4.3	+1.3	+0.7
Middle slope	+10.9	−1.1	−3.4	−0.1	−2.1	+0.1	+1.5	+0.9	+0.3	−5.0	+2.9	+2.4	+0.6
Southern slope	+9.7	−0.8	−3.5	0.0	+0.4	+0.7	+0.7	+1.5	+1.4	−3.2	−0.4	−2.4	+0.3
Southern Plateau	+4.6	−1.4	−2.7	−1.0	+1.5	−2.8	−0.1	−1.0	−1.2	−2.4	+0.6	−1.1	−0.6
Middle Plateau	+4.8	−5.2	−3.4	−2.0	+1.2	−3.6	+2.0	−1.3	−0.1	−2.9	+1.4	−2.3	−1.0
Northern Plateau	+6.2	−5.2	−0.3	−0.2	−0.3	−3.2	+2.6	+1.0	+2.6	−0.2	+2.1	−0.2	+0.4
North Pacific coast region	+1.6	−2.6	−0.1	+1.7	+0.1	+0.8	+1.4	+2.8	+2.2	+2.8	+3.4	+0.3	+1.2
Middle Pacific coast region	−1.6	0.0	+1.3	−0.2	−0.4	−2.8	+0.7	+1.2	+2.5	+0.1	+4.2	−1.2	+0.3
South Pacific coast region	+2.2	+0.6	+2.4	−0.5	+1.4	−3.0	−0.6	−0.8	+2.2	+1.5	+4.9	+0.8	+0.9
United States as a whole													+0.5

The excess of temperature in the last quarter of the year seems to be rather definitely tied up with low pressure in the Arctic and, moreover, it also seems to be rather clearly indicated that when pressure in high latitudes in the North American Continent and Asia is low, the prevailing drift of the atmosphere over Canada and the United States is from west to east *with few and unimportant exchanges of polar and equatorial air and vice versa.*

TROPICAL DISTURBANCES DURING THE HURRICANE SEASON OF 1923.

By W. P. DAY.

The word "hurricane" comes from a Carib word meaning "a high wind." But meteorologically it is now associated with the small, intense cyclones which occur in this region and are responsible for the really destructive winds. Fortunately, a great many tropical disturbances do not develop these characteristics; but it is often difficult to decide from available reports whether any particular disturbance originating over warm waters carries with it the central core of low barometer, which writes a typical hurricane trace on the barograph.

The first disturbance showing characteristics of a hurricane was noted on the morning of September 5 near latitude 36° N. and longitude 61° W., the S. S. *Evergreen City* reporting a pressure of 29.32 inches with force 10 (Beaufort wind scale) from the northeast. The storm appeared to be of small diameter, forming a small part of a larger depression or trough of low pressure extending northeast from Bermuda. Previously a rather ill-defined depression had been traced as it recurved around Bermuda; but it was not until the 5th that either low barometer or high wind was detected. Meanwhile, a high-pressure area had obtruded itself into the path of the storm and its direction of motion was changed from northeast to north-northwest and greatly retarded. The center of the storm was again noted on the morning of the 9th as it crossed the steamer lanes near latitude 41° N and longitude 58° 30′ W, the S. S. *Emergency Aid* recording a pressure of 29.20 inches at 3 p. m. with a wind force of 10 from the south. The storm was now under the influence of a LOW moving along the northern border and, being caught in its attendant upper currents, was carried rapidly north-northeast, but with diminishing intensity over, the colder waters of the Labrador Current.

The next disturbance also developed north of the Tropics but well within the Gulf Stream, and was first noted to be of hurricane intensity when the S. S. *Emergency Aid,* which had encountered the previous storm farther northeast, recorded a pressure of 29.42 inches and winds as high as force 11, on the morning of September 12, near latitude 36° N. and longitude 64° 30′ W. This storm was carried northeast much more rapidly than the preceding one and by 4 p. m. was near latitude 42° N. and longitude 60° W., the S. S. *City of St. Joseph* recording a pressure of 29.11 inches and wind force 12 from the northwest. Like its predecessor, it showed a marked loss of intensity upon striking colder water and there was but little indication of it on the following morning.

During September 23 unsettled conditions were noted to the southeast of Turks Island, the barometer falling slowly and wind shifts indicating the presence of a disturbance, which was more definitely located on the morning of the 25th, when the S. S. *Tulsa* reported a wind force of 10 from the northeast, pressure 29.86 inches, in latitude 23° 40′ N and longitude 74° W. The storm was moving northwest at this time and passed just east of Nassau, Bahamas, on the 26th, the morning barometer reading 29.54 inches and wind 40 m. p. h. from the northwest. However, a large high-pressure area was now blocking its forward motion and the storm, though not diverted from its recurve to the northeast, showed very little movement during the next two or three days, but gradually increased its area of influence and its intensity with winds of gale force over a large area and wind force as high as 11 reported by vessels which approached its center. It was not until the morning of the 29th that the eastward movement of

the HIGH allowed a strengthening of the southwest drift aloft and a corresponding acceleration in the northeastward movement of the storm. The hurricane was now near latitude 31° 30′ N. and longitude 73° with lowest pressure somewhat below 29 inches. The following morning the S. S. *Collegian* recorded the passage of the center of the storm in latitude 33° 20′ N and longitude 69° W. with lowest barometer reading, 28.62 inches. The S. S. *Maraval* near by recorded a pressure of 28.98 inches with a shift of wind from east-southeast through north to northwest and a wind force of 12. At 2 a. m. the following morning (October 1) the S. S. *West Cobalt* reported passing through the storm near latitude 41° 30′ N and longitude 59° W with lowest barometer 28.50 inches and wind force of 12. A little farther north the *Saxoleine* recorded a pressure of 28.59 inches at 10 a. m., the wind backing from south to east to north around to west-southwest. Turning northward to western Newfoundland, the hurricane lost intensity over colder water.

The next disturbance of this nature apparently originated in low latitudes off the Pacific coast of Guatemala and was central on the morning of the 13th of October southeast of the Mexican Pacific port of Salina Cruz on the Gulf of Tehuantepec. It moved rapidly northward across the Isthmus of Tehuantepec and the western Gulf of Mexico and was encountered by the steamships *Corning* and *El Siglo* during the evening of the 15th near latitude 27° 30′ N. and longitude 92° W. By the following morning it had crossed the Louisiana coast and was central near Vicksburg, Miss., with a pressure of 29.26 inches; and during the night of the 16th dissipated over Arkansas and southern Missouri. The contour of the isobars was considerably distorted from the ideal by a strong pressure gradient from northeast to southwest over the United States, which tended to squeeze the isobars together on the northeast quarter of the storm and throw them wide apart to the southwest. The closing up of the isobars was especially effective in the vicinity of Pensacola, Fla., which was about 250 miles from the path of the center but recorded the highest wind velocity (64 miles from the southeast) of any land station. The storm in general lacked the intensity near the center that we normally expect of a true hurricane.

Meanwhile, a disturbance became apparent just north of the Leeward Islands and began to move north-northeastward; but with the strengthening of a large high-pressure area to the north and northeast, the storm was slowed up and deflected to the northwest. It passed just northeast of Bermuda on the 17th and crossed the Atlantic coast near Nantucket, Mass., on the night of October 18th and was still in evidence near Boston the following morning. This storm lacked the intensity necessary to be classed as a hurricane, but the shape and distribution of the isobars showed a close resemblance to this type.

The severe storm of the 22d–25th of October, which developed north of the Bahamas and moved northward to Hatteras and thence north-northwestward to extreme northwest Pennsylvania, was formed and maintained by the usual processes attending extra-tropical storms and bore no resemblance to a hurricane. (See Chart XIII.)

NOTES, ABSTRACTS, AND REVIEWS.

THE PAN-PACIFIC CONGRESS, AUSTRALIA, 1923.

[Reprinted from *Nature*, Jan. 5, 1924.]

Among the many problems discussed by the congress the two following are of special interest to meteorologists, geographers and oceanographers, and are reproduced in full.

* * * *Pacific radiotelegraphy.*—The congress emphasized the importance of the speedy erection of wireless stations in all countries bordering the Pacific capable of communicating directly with each other. It recommended that arrangements be made for all wireless stations in Pacific regions to keep daily records on an approved basis with regard to atmospherics, their effect on wireless communication, and their relation to meteorological conditions. It was suggested that Governments of the different countries concerned should establish a daily mean time signal.

Geography and oceanography.—On the motion of Dr. N. Yamasaki, of the Imperial Observatory, Tokyo, it was agreed to urge the increasing importance of accurate coastal surveys being carried out in accordance with the recommendations of the International Hydrographic Bureau, and that special attention should be given to the scientific and economic interest of the construction of detailed charts of the Great Barrier Reef of Australia. The congress also invited attention to the need for an adequate wireless meteorological service in the more remote parts of the Pacific Ocean, and urged that the international exchange of meteorological information for the purpose of forecasting be extended to those regions.

* * * * *

COLD WEATHER IN EUROPE.

It is quite evident that the weather this winter in Europe has been characterized by severe storms and intense cold. Whether the winter as a whole will be classed among the severe ones can not of course be determined from press reports that reach this country from time to time. In the nature of the case the press dispatch is generally made up from a limited amount of reliable meteorological information and while the accuracy of the information presented therein is not questioned, its general character leaves much to be gleaned from the official meteorological reports of the several European countries.

An Associated Press dispatch from London summarizes the situation as follows:

JANUARY 10, 1924.

Unusually severe storms, accompanied by intense cold and heavy snow, are sweeping Europe this winter. Off the coasts of Spain and France the disturbances have proved a serious menace to shipping, while in the North Sea and in Scandinavian waters the ice floes are so heavy that navigation in many places is difficult.

Not in many years have there been so many casualties from avalanches in the Swiss-French Alps. Heavy rains in the lower passes and foothills of the latter mountains have contributed largely to the Marne and Seine floods in France.

England also is suffering, although in a lesser degree. The cold in this country is severe and there is much snow, especially in the midlands and in the north.

Wind, snow, and rain over all of western Europe have seriously delayed telegraphic communication. Until 6 o'clock this morning no press dispatches had reached England from Spain in more than 24 hours.

—*A. J. H.*

NEWS OF THE "MAUD."

[Reprinted from *Nature*, Dec. 15, 1923.]

News from the Norwegian expedition in the *Maud*, which is drifting across the Arctic Ocean, has appeared in the Times. The reports were sent out by the *Maud's* wireless installation and received by the Spitzbergen radio station. In March, 1923, the *Maud* was in latitude 74° 2′ N., longitude 170° 20′ E., and was drifting northwest. In September its position was latitude 76° 16′ N., longitude 163° 30′ E., when a long-continued northwest gale set in and drove the ship and pack ice toward the south, with a result that in the end of October it was in latitude 75° 10′ N., longitude 159° 30′ E. The current in that part of the polar basin is reported to be from the north-northeast, thus disposing of the likelihood, which was never strong, of extensive land to the northeast of the DeLong Islands. The *Maud* would appear to be drifting toward the New Siberia Islands, and, if it should succeed in passing to the north of that group, will traverse an interesting and unknown part of Arctic Seas; but there is little prospect of the drift taking her to a high northern latitude. Conditions proved unfavorable for the use of the aeroplane. Throughout the summer there was much mist and the temperatures were low. The floe offered few safe landing places. Several trial flights were disappointing, and the last one resulted in serious damage to the aeroplane. Scientific observations from the ship, especially current measurements, have been continued. Captain Wisting reports the death of Mr. Syvertsen, the ship's engineer.

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C. F. TALMAN, Meteorologist in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1923.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for April, 1920, **48**:225, and a note in the REVIEW for November, 1922, **50**:595.

From Table 1 it is seen that solar-radiation intensities averaged slightly above the normal values for December at all the stations.

Table 2 shows a slight deficiency in the total radiation received on a horizontal surface at all the stations.

For the year the deficiency was about 4.2 per cent at Washington and 1.7 per cent at Madison and Lincoln.

Skylight-polarization measurements obtained at Washington on two days give a mean of 64 per cent, with a maximum of 64.4 per cent on the 12th. At Madison a measurement on the 13th gave 72 per cent polarization. These are average values for the respective stations in December.

TABLE 1.—*Solar radiation intensities during December, 1923.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th mer. time.	Airmass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 7	3.99	.....	.....	.....	1.29	.....	.....	.....	.....	.....	4.17
11	4.57	0.96	1.08	1.15	**1.34**	1.50	.....	1.18	1.03	0.92	3.30
12	3.81	1.02	1.12	1.24	1.19	.....	.....	.....	.....	.....	5.37
14	3.30	.....	.....	.....	1.22	.....	.....	1.07	0.92	0.70	2.62
17	3.63	.....	.....	.....	1.27	1.46	.....	1.10	0.95	0.83	3.63
19	4.17	0.50	0.54	.....	1.15	.....	.....	.....	.....	.....	4.57
24	3.81	.....	.....	.....	1.37	.....	.....	.....	.....	.....	3.00
26	2.49	0.91	1.04	1.17	1.38	.....	.....	1.17	1.04	0.93	2.49
28	7.04	.....	.....	.....	1.42	.....	.....	1.15	0.95	0.82	3.15
29	3.00	0.82	0.93	1.04	1.25	.....	.....	1.03	0.90	0.80	2.74
Means	.....	**0.84**	**0.94**	**1.15**	**1.29**	.....	.....	**1.12**	**0.96**	**0.83**	.....
Departures	.....	**+0.06**	**+0.05**	**+0.10**	**+0.06**	.....	.....	**+0.10**	**+0.07**	**+0.06**	.....

TABLE 1.—*Solar radiation intensities during December, 1923*—Con.

[Gram-calories per minute per square centimeter of normal surface.]

Madison, Wis.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th mer. time.	Airmass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 6	3.00	0.92	1.06	1.23	1.42	.....	.....	.....	.....	.....	4.37
10	3.30	.....	.....	.....	.....	.....	.....	1.23	.....	.....	3.15
11	2.06	.....	.....	1.28	.....	.....	.....	1.28	.....	.....	2.49
13	1.78	.....	.....	1.28	.....	.....	.....	.....	.....	.....	1.45
14	1.96	0.94	1.08	1.24	.....	.....	.....	.....	.....	.....	3.30
24	3.45	.....	0.93	.....	.....	.....	.....	.....	.....	.....	3.81
Means	.....	(0.93)	**1.02**	**1.26**	(1.42)	.....	.....	(1.26)	.....	.....	.....
Departures	.....	**−0.03**	**−0.10**	**+0.04**	.....	.....	.....	**−0.04**	.....	.....	.....

Lincoln, Nebr.

Dec. 4	3.15	.....	.....	.....	.....	.....	.....	1.22	1.05	0.95	3.81
5	2.36	.....	.....	.....	1.10	.....	.....	.....	.....	.....	3.45
8	4.75	.....	.....	.....	1.33	.....	.....	.....	.....	.....	4.17
10	3.45	.....	.....	.....	.....	.....	.....	.....	.....	1.03	3.45
13	1.88	1.07	1.22	1.36	.....	.....	.....	1.34	.....	.....	2.26
14	2.26	.....	.....	1.27	1.44	.....	.....	.....	.....	.....	2.36
15	3.81	.....	.....	1.18	.....	.....	.....	.....	.....	.....	4.57
17	2.36	.....	1.04	1.23	.....	.....	.....	1.27	1.13	1.04	3.00
18	3.45	.....	.....	1.25	.....	.....	.....	.....	.....	.....	4.37
Means	.....	(1.07)	(1.13)	**1.26**	**1.29**	.....	.....	**1.28**	(1.09)	**1.01**	.....
Departures	.....	**+0.14**	**+0.08**	**+0.03**	**−0.07**	.....	.....	**+0.08**	**+0.02**	**+0.06**	.....

[1] Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.				Average daily departure for the week.			Excess or deficiency since first of year.		
	Chicago.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 3	61	142	95	194	−14	−28	+15	−5,120	−1,639	−2,077
10	110	173	146	194	+21	+23	+17	−4,970	−1,477	−1,955
17	63	121	78	131	−29	−47	−45	−5,175	−1,809	−2,269
[2] 24	71	139	102	164	−13	−30	−15	−5,278	−2,045	−2,386

[2] For 8 days.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The following figures show the average pressure and departure for the month at a number of selected stations on the coast and islands of the North Atlantic. The barometric readings are in inches, for 8 a. m., 75th meridian time, and the departures are only approximate, as the normals were taken from the Pilot Chart, and are based on Greenwich mean noon observations, or 7 a. m., 75th meridian time.

St. Johns, Newfoundland, average 29.82, departure ±0.00. Nantucket, 30.15, +0.08. Hatteras, 30.15, +0.03. Key West, 30.12, +0.03. New Orleans, 30.12, ±0.00. Swan Island, 29.94, −0.05. Turks Island, 30.13, +0.11. Bermuda, 30.12, +0.04. Horta, Azores, 30.35, +0.18. Lerwick, Shetland Islands, 29.95, +0.16. Valentia, Ireland, 30.05, +0.12. London, 29.97, −0.05.

With the exception of January, December is the stormiest month of the year over the North Atlantic, and judging from reports received, the month under discussion was no exception to the general rule, as over the greater part of the ocean the number of days with winds of gale force did not differ materially from the normal as shown on the Pilot Chart. A number of vessels reported from three to six separate gales of varying intensity, on the trans-Atlantic voyage.

Fog was apparently somewhat less frequent than usual over the Grand Banks, and the number of days on which it occurred over the steamer lanes and off the American and European coasts was not far from the normal.

From the 1st to 8th an area of low pressure was in the vicinity of the European coast, causing turbulent weather over the eastern section of the steamer lanes, although the storm area varied considerably from day to day during this period. Storm logs:

American S. S. *Duquesne:*

Gale began on the 1st, wind W. Lowest barometer 29.92 inches at noon on the 1st, wind W., 9, in latitude 48° 06′ N., longitude 16° 14′ W. End on the 2d, wind NW. Highest force of wind 9, W.; shifts W.–NW.

British S. S. *Bolivian:*

Gale began on the 3d, wind W. Lowest barometer 29.44 inches at 3 p. m. on the 3d, wind W., 8, in latitude 50° 52′ N., longitude 23° 30′ W. End at 8 p. m. on the 5th, wind NNW. Highest force of wind 12, W.; shifts W.–NNW.

American S. S. *Coelleda:*

Gale began on the 5th, wind N. Lowest barometer 28.97 inches at 10 a. m. on the 5th, wind N. 8, in latitude 51° 20′ N., longitude 9° 45′ W. End on the 8th, wind NNW. Highest force of wind 10; shifts SW.–W.–NW.

The daily weather map for the morning of the 5th shows a well-developed area of low pressure over the southern portion of the United States; this moved rapidly northward and on the 6th was central near Buffalo, N. Y. This LOW was responsible for southerly to westerly gales over a limited area off the coasts of the Carolinas and Georgia, as shown by following storm log:

American S. S. *Antilla:*

Gale began on the 5th, wind SW. Lowest barometer 29.63 inches at 1 a. m. on the 6th, wind SW., 9, in latitude 32° 55′ N., longitude 77° 10′ W. End on the 6th, wind W. Highest force of wind 9, SW.; shifts SW.–W.

From the 9th to 12th the Icelandic LOW appeared to be unusually well developed, and moderate to strong gales prevailed during this period between the 10th and 45th meridians. Storm log:

American S. S. *Coelleda:*

Gale began on the 9th, wind SW. Lowest barometer 29.32 inches at 8 a. m. on the 9th, wind SW., 8, in latitude 49° 50′ N., longitude 30° 30′ W. End on the 11th, wind WNW. Highest force of wind 10 NW.; shifts SW.–W.–NW.

On the 8th and 9th there was a well-developed disturbance near the Azores, as shown by the following storm logs:

Belgian S. S. *Emanuel Nobel:*

Gale began on the 8th, wind NE. Lowest barometer 29.83 inches at 2 a. m. on the 8th, wind NE., 10, in latitude 37° 57′ N., longitude 25° 08′ W. End on the 8th, wind NE. Highest force of wind 10; steady NE.

Danish S. S. *Dania:*

Gale began on the 8th, wind NE. Lowest barometer 29.95 inches at noon on the 8th, wind NE., 7, in latitude 39° 53′ N., longitude 25° 15′ W. End on the 9th, wind ESE. Highest force of wind 8; steady NE.

On the 12th St. Johns, Newfoundland, was near the center of a moderate depression that moved rapidly northward, and on the 12th and 13th a number of vessels encountered gales over the northern steamer lanes, although no unusually heavy winds were reported.

On the 13th and 14th unusual conditions for the winter prevailed in southern waters. On the 13th a vessel near latitude 29° N., longitude 51° W., recorded a northerly wind, force 8, barometer 29.91 inches. Unfortunately no other reports have been received for that date from this vicinity, although on the 14th there was undoubtedly a shallow depression central near latitude 30° N., longitude 45° W., with northerly to northeasterly gales in the westerly and northwesterly quadrants, while a vessel near latitude 28° N., longitude 40° W., reported a southerly wind, force 7. Storm logs:

American S. S. *Saguache:*

Gale began on the 13th. Lowest barometer 29.90 inches at 9 a. m. on the 13th, wind N., 8, in latitude 29° N., longitude 50° 32′ W. End on the 15th. Highest force of wind 8, N.; shifts N.–NE.–E.

American S. S. *Vincent:*

Gale began on the 12th, wind S. Lowest barometer 29.93 inches at 2 p. m. on the 14th, wind N., in latitude 35° N., longitude 48° W. End on the 14th, wind ENE. Highest force of wind, 9, N.; shifts S.–N.

On the 14th there were unusually heavy northerly to northeasterly winds, accompanied by comparatively high barometric readings, in the Gulf of Mexico and also in the vicinity of Hatteras.

On the 15th abnormally high pressure prevailed along the American coast, with a shallow depression central near latitude 43° N., longitude 57° W. Gales of anticyclonic origin were reported by a number of vessels west of the 65th meridian. Storm log:

American S. S. *Coelleda*:

Gale began on the 15th, wind NNW. Lowest barometer 29.89 inches at 8 a. m. on the 15th, wind NNW., 9, in latitude 43° 12′ N., longitude 55° 15′ W. End at 11 p. m. on the 15th, wind NNW. Highest force of wind 9; steady NNW.

On the 16th and 17th the general conditions over the ocean were quieter than usual, although on the former date a number of vessels encountered moderate gales in widely scattered localities, while a "norther" prevailed in the Gulf of Mexico. Storm log:

Honduran S. S. *Yoro:*

Gale began on the 16th, wind NE. Lowest barometer 29.99 inches at 5.30 p. m. on the 16th, wind NNW., in latitude 20° 21′ N., longitude 95° 18′ W. End on the 17th, wind ESE. Highest force of wind 9; shifts 6 points.

On the 18th two well developed LOWS appeared; the first in the vicinity of Newfoundland and the second over the North Sea.

On the 19th the eastern LOW did not appear within the limits of the map, while the movement of the western disturbance was slight during the next 4 days. From the 19th to 21st moderate to strong northerly gales swept over the region between the 30th and 45th parallels and the 55th and 65th meridians. Storm logs:

American S. S. *Ophis:*

Gale began on the 19th, wind NW. Lowest barometer 30.06 inches at 4 a. m. on the 19th, wind NW., 9, in latitude 33° 20′ N., longitude 56° 40′ W. End on the 21st, wind NW. Highest force of wind 9, NW.; steady NW.

American S. S. *Innoko:*

Gale began on the 18th, wind NNW. Lowest barometer 29. 82 inches at noon on the 21st, wind NW., 7, in latitude 40° 53′ N., longitude 54° 17′ W. End on the 21st, wind NW. Highest force of wind 8; shifts NNW.–NW.

On the 23d westerly to southwesterly gales were reported near Hatteras, and the third "norther" of the month made its appearance in the Gulf of Mexico.

On the 24th heavy winds continued along the American coast and storm logs were received from vessels as far east as the 54th meridian. On the same day an area of low pressure covered a portion of Great Britain, accompanied by westerly gales off the southern coast of England.

On the 25th the western disturbance was central near latitude 35° N., longitude 65 °W., and winds of gale force were encountered in the vicinity of the Bermudas. Storm log:

British S. S. *Bradford City:*

Gale began on the 25th, wind SW. Lowest barometer 29.69 inches at 3 p. m. on the 25th, wind SW., 9, in latitude 34° N., longitude 57° 50′ W. End on the 27th, wind NW. Highest force of wind 9; shifts SSW.–SW.–WNW.

On the 25th a second depression appeared near latitude 52° N., longitude 55° W., with southerly gales in the easterly quadrants.

On the 26th the western disturbance was central near latitude 42° N., longitude 42° W., while it was impossible to locate the eastern LOW on account of lack of observations. Storm logs:

British S. S. *Aral:*

Gale began on the 26th, wind SW. Lowest barometer 29.58 inches at 3 a. m. on the 26th, wind SW., 9, in latitude 41° 20′ N., longitude 44° 40′ W. End on the 27th, wind SW. Highest force of wind 9; shifts SW.–W.–SW.

American S. S. *Conness Peak:*

Gale began on the 25th, wind SW. Lowest barometer 29.91 inches at 4 p. m. on the 25th, wind W., 9, in latitude 46° 39′ N., longitude 11° 52′ W. End on the 28th, wind NW. Highest force of wind 9, NW.; shifts WSW.–W.

Charts VIII to XII show the conditions from the 27th to the 31st, inclusive, during which period the heaviest storms of the month occurred, as the ocean was swept by gale after gale, the wind at times attaining hurricane force. A glance at the charts will show the different areas of LOW pressure that caused these conditions, and also how the storm area varied in extent from day to day.

British S. S. *Manchester Merchant:*

Gale began on the 26th, wind SW. Lowest barometer 29.53 inches at 4 a. m. on the 27th, wind WNW., in latitude 40° 28′ N., longitude 49° 02′ W. End on the 30th, wind W., 10. Highest force of wind 10; shifts SW.-WNW.-SSW.

British S. S. *Galtymore:*

Gale began on the 27th, wind SE. Lowest barometer 28.89 inches at 2 a. m. on the 28th, wind WSW., 12, in latitude 48° 26′ N., longitude 45° 08′ W. End on the 28th, wind WSW. Highest force of wind 12; shifts SSW.-WSW.

French cable S. S. *Edouard Jeramec:*

Gale began on the 28th, wind SE. Lowest barometer 28.68 inches at 2:30 a. m. on the 29th, wind WNW., in latitude 43° 30′ N., longitude 63° 40′ W. End on the 30th, wind WNW. Highest force of wind 10; shifts ESE.-SE.-SW.-NW.-WNW.

British S. S. *Aral:*

Gale began on the 28th, wind SW. Lowest barometer 29.59 inches at noon on the 29th, wind SW. 10, in latitude 36° 30′ N., longitude 52° 08′ W. End on the 30th, wind NW. Highest force of wind 12; shifts SW.-W.-WNW.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

In the report for the preceding month it was indicated that November, as regards the severity of the weather, lay between months having periods of maximum activity. December opened in the Far East with the entrance upon the ocean of an extensive area of high pressure from Mongolia. The North Pacific HIGH was practically normal in location and pressure, and the Aleutian cyclone was central as a major disturbance over the Gulf of Alaska. Between these two great atmospheric pressure extremes of the eastern Pacific a sharp gradient existed which, on December 4, covered a range of 2.31 inches, or between 30.32 and 28.01 inches within latitudes 35° and 50° N., longitudes 155° and 161° W. In consequence of such conditions strong gales to full hurricane winds prevailed along the northern shipping routes to the eastward of the 170th meridian of west longitude from the 1st to the 6th of the month.

During the period of maximum intensity of this storm, which occurred on the 3d to 5th, six vessels encountered winds of hurricane force. These were the Japanese S. S. *Yogen Maru*, the British S. S. *Mongolian Prince*, and the American steamships *Dewey*, *Northwestern*, *President Madison*, and *West Jena*. With the exception of the *West Jena*, these vessels were eastward bound.

The *Yogen Maru*, Capt. G. Kuwana, Observer K. Sato, passed through the heaviest winds on the 3d, direction west-northwest, lowest pressure 28.41 inches, in latitude 50° 50′ N., longitude 165° 45′ W. The *Mongolian Prince*, Capt. J. Chilvers, Observer H. A. Shaw, experienced gales from the 1st to the 6th, along the 49th parallel, between longitudes 169° W., and 140° W., accompanied by fierce rain, snow, or hail squalls. On the 2d the wind attained a force of 11 from the west-southwest, lowest pressure 28.71 inches, in 49° 16′ N., 165° 53′ W. On the 4th the highest wind was from the west, force 12, lowest pressure 28.71 inches, in 49° 32′ N., 146° 35′ W. On the 5th the vessel still was in the terrific gale, highest force 11, west-southwest, with precipitous seas. The wind moderated and pressure rose on the 6th.

The *Dewey*, Capt. C. Ash, Observer L. A. Snyder, bore the brunt of the hurricane on the 4th. At Greenwich mean noon the vessel was in 50° 12′ N., 162° 26′ W., pressure 28.16, experiencing a whole gale from the south. It was followed by hurricane velocities, and lowest pressure of 28.01 inches. At G. M. N. of the 5th, in 48° 56′ N., 157° 39′ W., there was still a whole gale from the south, pressure 28.12 inches, but shortly afterward conditions moderated.

The *West Jena*, Capt. P. T. Hansen, Observer T. V. Hughes, had a rough voyage between Portland, Oreg., and Japan. Stormy conditions began on December 1, near 49° 22′ N., 135° 50′ W., and continued until after the 17th, when in 49° N., 173° 55′ E. She experienced the hurricane of the 5th, near 50° 30′ N., 147° W., wind northwest, lowest recorded pressure 28.80 inches. Several other vessels involved in this storm encountered winds of forces 10 and 11.

On the 6th an important offshoot of the cyclone entered the Canadian northwest and traversed the northern part of the United States during the succeeding two or three days.

Occasional gales of force 7 or 8 were reported from the northern courses in east longitudes during the first ten days of the month, but there seems to have been no decided storm activity in these waters during this decade.

The Aleutian center until the 10th was practically confined to the eastern area. On this date, however, a disturbance from the west appeared, and two centers of minimum pressure were apparent over northern waters. Gales were not extensively reported at this time, although violent winds occurred over various sections of the middle and northern routes east of 170° west longitude on the 9th to 12th. Later, or from the 11th to the 17th, stormy conditions prevailed to the westward.

The British S. S. *Ocean Prince* encountered heavy squalls while running up the coast between North Head and Vancouver on the 9th to 11th. During the early half of the period a strong HIGH was entering the northwest coast of the United States. With falling barometer, late on the 10th, the *Ocean Prince* for a time proceeded in a southerly gale, highest force 12, lowest pressure 29.77, in 48° 07′ N., 125° 17′ W. North Head recorded a 73-mile wind on the 11th.

On the 12th three steamships near 45° N., 162° E., were caught in severe weather during the passage of a cyclone. The American S. S. *Crosskeys* reported a west-northwesterly gale, force 11, lowest pressure 29.48. The Japanese S. S. *Shidzuoki Maru* encountered a northwesterly gale, force 10, lowest pressure 29.61. The Japanese S. S. *Nankai Maru* also reported a whole gale from the west-northwest, lowest pressure 29.38. This storm was closely followed by a strong anticyclone.

Late on the 9th a slight disturbance appeared near the Hawaiian Islands, and on the 10th was central somewhat to the north-northeastward, with moderate gain in energy. The storm moved northward and by the 13th was occupying a position in the eastern Gulf of Alaska. Gales as high in force as 10 attended this storm, being noted on the 10th and 11th near latitude 33° N., longitude 157° W., by the American S. S. *Melrose*. North Head station on the 13th experienced an 80-mile gale from the southwest.

From the 15th to the 17th of the month storm conditions approximating in energy those of the 4th and 5th in more eastern waters settled over the northern routes between 45° and 50° N., and 160° E. and 170° W. The storm had swept seaward from northern Japan on the 13th, accompanied by gales of reported forces 9 to 11 which extended through the 14th.

On the 15th, in latitude 48° 32′ N., longitude 179° 05′ E., the American S. S. *West Cayote* experienced a southeasterly gale, force 12, lowest pressure 29.32 inches. On the following day the Japanese S. S. *Nankai Maru* fell in with a westerly gale, force 11, lowest pressure 29.07, in 49° 52′ N., 175° 30′ E. On the 17th hurricane velocities from a westerly direction were encountered by the Japanese S. S. *Toku Maru*, in 50° 05′ N., 174° 16′ E., lowest pressure 29.10; by the British S. S. *Doonholm*, in 47° 30′ N., 165° E., lowest pressure 29.22; and by the American S. S. *West Jena*, in 49° N., 173° 55′ W., lowest pressure 29.64. After this date the storm seems to have lost energy.

During a storm which lay off the coast of Canada and northern United States on the 17th, North Head recorded a maximum wind velocity of 88 miles from the south. Reports at sea some distance to the southward and westward indicate only light to moderate gales at this time.

On December 20 a general intensification of storm conditions took place over the northeastern part of the Pacific. Near 41° N., 164° W., the American S. S. *Manulani* reported a southwesterly gale, force 9, pressure 29.18, and the American S. S. *Northwestern* entered upon a period of stiff southerly gales which lasted until the 22d, while the vessel was off the Alaskan coast above Sitka. On the 21st the American S. S. *Crosskeys* was beset by a south gale, force 10, lowest pressure 29.40, in 49° 36′ N., 135° 12′ W.

A second depression formed in the neighborhood of Hawaii during the 23d and 24th, and gave some gales of force 8 to the northeastward of the islands on the 24th. It had moved westward on the 25th, and on the 26th lay to the northeastward of Midway Island, whence it seems to have moved into the Aleutian area on the 29th or 30th.

Another storm entered the Oregon, Washington, and British Columbia coasts on the 24th and 25th. This did some damage to shipping, and, on the 25th, broke all previous records for high wind velocities at Tacoma and Seattle: at Tacoma with a maximum wind of 52 miles, and at Seattle, with 66 miles, both from the south. At Gray's Harbor an 80-mile gale lashed the coast. At North Head the highest velocity was 72 miles an hour from the south, on the night of the 24th. The storm was accompanied by almost unprecedented lightning for December. Few vessel reports of this storm are at hand, and these give no wind-force higher than 10. After crossing the United States, the cyclone entered the North Atlantic Ocean vigorously on the 28th and 29th.

Severe gales occurred to the southward of the Aleutian Islands on the 24th, due to a strengthening of the cyclonic conditions to the westward of Dutch Harbor. The American S. S. *Bearport*, bound toward Seattle, reported the highest force of wind, SSE. 11, in connection with the storm, in latitude 49° 10′ N., longitude 178° 13′ E., lowest pressure 29.15.

On December 25 and 26 an Asiatic cyclone entered the sea from northern Japan. While no very low pressures were observed during its passage, several vessels within its influence were involved in strong to dangerous gales. The American S. S. *Tejon*, in 40° N., 146° 50′ E., on the 26th, encountered a southwest gale, force 10, lowest pressure 29.69 inches, accompanied by severe electrical phenomena. The British S. S. *Canadian Transporter*, eastward bound, experienced whole gales to hurricane winds, from the west to northwest on the

26th and 27th, lowest pressure 29.50. On both days the ship's position was near 41° N., 153° E. Southerly gales, force 10, occurred near the 180th meridian on tne 27th and 28th, and were reported by the American S. S. *West Jessup*, eastward bound, in latitudes 47° to 48° N.

At the close of the month moderate to whole northwesterly gales occurred off the American coast from northern California to Washington, following the passage inland of a slight depression. These gales were apparently severest between 40° and 50° N., near and along the 130th meridian.

Variable weather was met with along the American coast from Panama to San Diego. Calms and light airs were frequent, although gales of forces 7 to 10 occurred on several days. The strongest winds, as usual, blew from the Gulf of Tehuantepec.

In the lower Far East two tropical storms occurred. These receive mention below.

Pressure for December, 1923, based on p. m. observations taken at the island stations, was at Honolulu the same as the average, at Dutch Harbor slightly below, and at Midway Island much above average. The average for the month at Midway Island was 30.20 inches, whereas that for the 12 years of record, 1912 to 1923, inclusive, is but 30.03. The previous high value was 30.14, in 1918. The highest pressure of the month, 30.38, was recorded on the 10th, 11th, and 12th; the lowest, 29.74, on the 26th. The p. m. pressure at Dutch Harbor was 29.52 inches, as compared with an average of 29.55. The highest pressure, 30.16, was recorded on the 15th, 23d, and 27th; the lowest, 28.52, on the 4th—absolute range 1.64 inches. The p. m. pressure at Honolulu was 30.01 inches, which is the same as the normal. The highest pressure, 30.12, occurred on the 16th; the lowest, 29.77, on the 23d.

The North Pacific high-pressure area, while it fluctuated in size and intensity, was broken up comparatively little during December. The Hawaiian storms of the 10th and 24th were the main disturbing elements to the HIGH, except from the north, whenever the Aleutian cyclone oscillated southward.

The weather at Honolulu was fine, but the cloudiest on record. The average wind velocity was 10 miles per hour, with velocities exceeding 35 miles per hour on the following dates: 39 NE., 12th; 39 NE., 15th; 41 NE., 16th; 37 NE., 17th. The prevailing direction was east.

Very little fog was reported by ocean observers. The heaviest percentage occurred outside of San Francisco harbor, where it was noted on five days. In addition scattered occurrences were reported off the coast of southern California, along the northern steamer routes, and to the eastward of Japan.

TWO TYPHOONS IN THE FAR EAST DURING DECEMBER, 1923.

By REV. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

There were only two typhoons in the Far East during the last month of December—one over the southern part of Luzon and the other over the Pacific to the east of the southern part of the Philippines.

The first typhoon appeared on the 3d to the NE. of Samar and E. of the southern part of Luzon near 127° longitude E., and between 13° and 14° latitude N. It moved W. by N. on the 3d and then inclined to W. and and W. by S. on the 4th. The body of the storm was very small, the barometer at Daet (about 120 miles E. by S. of Manila) having fallen to 740.75 mm.,[1] 29.16 inches, at 2 p. m. of the 4th, while in Manila it was as high as 760 mm., 29.92 inches. The center passed over the northern part of Camarines Norte, over 100 houses and many big trees having been blown down in the town of Paracale, where this typhoon is considered as one of the strongest typhoons experienced there in many years.

The intensity of the typhoon decreased considerably while traversing the northernmost part of Camarines Norte and the southern part of the Province of Tayabas. The center passed during the night about 50 miles to the south of Manila moving W. by S. or WSW.

The other typhoon was of hardly any importance for the Philippines. It appeared south of Yap on the 18th near 138° longitude E. and between 6° and 7° latitude N., and moved W. by N. until the 20th, when it recurved slowly to the north and northeast near 130° longitude E. and between 7° and 11° latitude N. On the 24th the center was still shown by our Weather Maps in about 134° longitude E., 19° latitude N. moving NE. or ENE., it having been impossible to follow it after the 24th.

TROPICAL CYCLONE IN THE NORTH INDIAN OCEAN.

The British S. S. *Cyclops*, Capt. W. Cosker, proceeding from Suez to Singapore, on December 19, while southwest of the Laccadive Islands, encountered a tropical cyclone moving in a westerly direction. Observers C. A. Blow, second officer, and R. W. Ellis, fourth officer, reported the following:

December 18th, midnight. Overcast, frequent rain squalls. Wind N., force 4.

December 19th, 4 a. m.: Continuous rain. Moderate NE. sea. Wind N., force 4. 9:30 a. m.: Barometer 29.68 inches (uncorrected), commenced falling. Heavy rain. Wind N., force 6. Noon. Latitude 9° N., longitude 67° E. Heavy rain. Wind NW., force 7. Rough sea. Bar, 29.44 inches. 0:55 p. m.: Hove to. 2:30 p. m. to 3 p. m. Heavy squall, force 12. Barometer 29.08 inches, with wind shifts from NW. to W. High NW. and w'ly sea. 3:30 p. m.: Similar conditions, barometer 29.22 inches. 4 p. m.: Wind SW. by W., force 8, same confused sea, barometer 29.29 inches. 4:30 p. m.: Weather moderated, sky cleared, rain ceased, vessel kept away on course. 8:30 p. m.: Wind SE., force 4–5, barometer 29.63 inches. Slight w'ly swell. (*A. J. McC., jr.*)

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

By ALFRED J. HENRY.

The outstanding characteristic of the month was the continued low pressure in Alaska and thence southward to about 50° north latitude. As a direct result the drift of the atmosphere over the United States and Canada was, in general, in an east-west direction with remarkably few interruptions in a north-south direction. Anticyclones came in from the Pacific and moved rapidly across the country, yet east of the Rocky Mountains the temperature was exceptionally mild for the season. The usual details follow.

[1] Gravi y correction not applied.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

About half of the low-pressure areas were of the Alberta type with centers of minimum pressure north of the Canadian border. The really important storms of the month were two from the North Pacific and a secondary development over central districts.

HIGHS were mostly of North Pacific origin and were not important factors in temperature control. The only Alberta HIGH of the month appeared in the northwest about the 29th and was responsible for the only important temperature reduction. In fact, the character and movement of the high and low pressure areas were about as would be expected considering the abnormal warmth which prevailed over most sections.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

The abnormally high mean temperatures, particularly at the northern aerological stations, present the most striking feature of the free-air conditions for the month. (See Table 1.) An intense cold wave occurred at the close of the month reaching Ellendale late on the 28th, Drexel on the 29th, Broken Arrow early, and Groesbeck late, on the 30th. The severity of this cold wave appreciably affected the monthly means and to exclude its influence at Ellendale, for example, would be to increase the monthly mean 2° C. When this is taken into consideration it is even more clearly seen how exceptionally warm the greater part of the month was. In general, at the northern stations the departures decreased with increase in altitude while at the southern stations the reverse was true.

Relative humidity departures were mostly negative at those stations having large positive temperature departures, being small at practically all stations except Groesbeck where they were considerably above normal for all levels.

Vapor pressures were mostly above normal except at Ellendale where an appreciable deficiency in the monthly precipitation occurred. At Groesbeck the reverse condition was found, vapor pressures being unusually high considering the average temperatures at this station, while a great excess of precipitation fell during the month.

The resultant winds as shown in Table 2 did not differ essentially from their normals, the largest variations being found at Drexel and Due West, where the monthly values contain either a more southerly or less northerly component and at Groesbeck a smaller southerly component than normally. This is in harmony with the average temperatures found at these stations.

Pilot-balloon observations from 13 stations east of the Rocky Mountains show the resultant winds at the surface for the month to have been from a southerly quarter except at Ellendale. A north component becomes dominant, however, at stations to the southward with increasing elevation so that at 4,000 m. all of the stations, including Key West, have a north component.

An unusual turning of the wind with altitude occurred over the Plains States on the 4th. The map of this date shows a LOW of wide extent central over the lower Mississippi Valley and high pressures to the westward with another disturbance approaching from the northwest. Both morning and afternoon pilot-balloon observations at Ellendale and Drexel showed northeast winds above 3,000 m., continuing to at least the level of the stratosphere. As a rule upper easterly winds are not of very great velocity but in this case a steady increase occurred, reaching 40 m. p. s. (90 m. p. h.), at the highest levels. It is noted that by the following day the Mississippi LOW had greatly increased in intensity and it seems probable, therefore, that the upper northeasterly winds at Ellendale and Drexel were part of this cyclonic circulation.

On the next day (5th) an unusual temperature distribution prevailed over the middle of the country when a strong temperature inversion at Ellendale caused a rise of 14°C. from the surface to 350 m. altitude. Above this, the temperatures continued higher at this station than at those to the southward, as far as Groesbeck. This condition extended to unusually high altitudes and at the highest point reached by the kites the temperatures at Ellendale continued 5°C. higher than at Broken Arrow. The following table shows the temperatures and wind directions observed this date.

Altitude, M. S. L. meters.

Stations.	Time.	Surface.	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000	3,500	4,000	4,500
		Wind directions and temperatures (°C.).												
Ellendale	8 a. m.	SSW. −5.5	.....	SSW. −3.2	SSW. 7.0	SW. 7.9	SW. 7.2	WSW. 6.5	W. 4.4	WNW. 1.5	NW. −1.6	NW. −5.1	NW. −8.5	.....
Drexel	6 p. m.	S. 1.6	.....	S. 2.8	S. 1.8	SW. 3.2	WSW. 2.6	W. 1.3	WNW. −1.3	WNW. −1.7	.....	.....	.....	.....
Broken Arrow	9 a. m.	N. 1.5	N. 1.4	N. −0.3	NNW. −2.0	NNW. −3.1	N. −1.6	N. −2.4	NNW. −4.1	NNW. −5.3	NNW. −7.7	NNW. −10.1	.....	.....
Groesbeck	8 a. m.	NW. 4.3	NW. 4.5	NW. 4.9	NW. 4.3	NW. 2.7	NW. 1.1	NW. 0.8	NW. −1.0	NW. −3.5	NW. −5.8	NW. −6.5	NW. −8.7	−10.9

For the explanation of such a reversal of the normal temperature gradient we inquire first as to the source of the imported air. It is found that on this morning Ellendale was in the southern quadrant of a strong LOW with SSW. winds at the surface, veering to WNW. at 2,000 m. and backing to WSW. at 6,000 m. That the air brought in over the northern stations was relatively warm is conclusively shown in the above table. The high temperatures at Ellendale did not continue long as is shown by a "series" of continuous kite flight made here on this date. The rapid eastward movement of this LOW caused the winds here soon to shift to NW. at all levels and the free-air temperatures fell steadily throughout the day. The flight at Drexel was not made until evening and so is not comparable in view of the rapid movement of the pressure areas. Flights at Broken Arrow and Groesbeck, however, made at the same time as at Ellendale, were under the influence of the LOW central over the Ohio Valley and winds were mostly N. at all levels.

During the period 16–18, inclusive, there occurred over the interior of the country easterly winds extending to 5,000 m. and higher. These are shown in the following table.

Altitude, m. s. l., meters.

Stations.	Surface.	500	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000
	Wind directions and velocities, m. p. s.													
Broken Arrow:														
16 a	N.-2	NE.-7	NE.-8	ENE.-10	ENE.-14	ENE.-20	E.-14							
16 p	NNW.-2	ENE.-3	NE.-4	E.-12	E.-15	ENE.-13	ENE.-13	E.-12						
17 a	NNE.-3	SSE.-3	S.-2	ESE.-9	E.-7	E.-8	E.-5	NW.-3	SW.-12					
17 p	N.-1	S.-1	SE.-2	ESE.-8	ESE.-8	ESE.-6	ESE.-4	SSE.-5						
18 a	NE.-2	SSE.-7	SSE.-7	SE.-15	SE.-15									
Denver:														
15 p	S.-4	S.-3	WNW.-2	ENE.-5	NNE.-9	NE.-11								
16 p	SSW.-6	SSW.-7	S.-6	N.-3	N.-2	NNE.-3								
17 p	S.-2	S.-2	S.-3	ESE.-3	ESE.-4	E.-6	ESE.-4							
18 p	NW.-1	NE.-2	NE.-2	E.-5	ESE.-8									
Drexel:														
17 p	SSW.-10	WSW.-17	WSW.-17	WSW.-12	W.-12	W.-9	W.-7	NW.-4	NNE.-7	NNE.-6	ENE.-10	NE.-7	WNW.-8	NW.-15
Memphis:														
16 p	E.-2	NE.-5	ENE.-10	ENE.-8	ENE.-5	NNW.-3								
17 p	NE.-3	NE.-7	NE.-7	ENE.-5	ENE.-6									

The pressure was above normal over this region at the time and it is found that the temperatures up to considerable altitudes were higher to the northward than to the southward. In fact, at Ellendale on the 18th all previous December high records were broken from 1,000 m. to 3,000 m. This reversal of the normal horizontal temperature gradient resulted in the easterly winds observed.

During the cold wave at the end of the month kite observations showed remarkable strong temperature inversions extending to great heights. For example, Ellendale on the 31st had a temperature only 2° C. lower at 2,850 m. altitude than at the surface; on the 30th at Drexel the temperature at 1,250 m. was 8° C. higher than at the surface; on the 31st only 4° C. lower at 2,200 m. than at the surface; at Broken Arrow on the 30th it was 6° C. higher at 1,730 m. than at the surface, while at Groesbeck it was 12° C. higher at 1.960 m. than at the surface. Such marked inversions are infrequent and are only found during severe cold waves.

Lansing reported on the 9th a light NE. wind extending to 2,000 m. where a backing occurred to WSW. with a rapid increase in velocity reaching 54 m. p. s. (121 m. p. h.) at 6,000 m., the highest level. At the time this station was on the eastern edge of an extensive HIGH with a steep south to north horizontal temperature gradient prevailing over this region. On the 12th Due West observed a wind of 47 m. p. s. (105 m. p. h. from NW. at 11,000 m. This occurred in the center of a circular HIGH which during the next 24 hours moved rapidly eastward. Key West on this date reported 33 m. p. s.(74 m. p. h.) from the NNW. at 10,000 m.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1923.*

TEMPERATURE (°C.).

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (444 m.)		Groesbeck, Tex. (141 m.)		Royal Center. Ind. (225 m.)	
	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 9-yr. mean.	Mean.	Departure from 3-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 6-yr. mean.
Surface	6.4	+0.7	− 0.5	+3.2	10.7	+1.4	−5.3	+2.4	10.2	0	2.6	+3.3
250	6.3	+0.6	.....	.....	10.6	+1.4	.....	.....	9.7	−0.3	2.6	+3.4
500	5.3	+0.3	−0.3	+3.3	9.9	+1.2	−4.9	+2.6	8.9	−0.6	2.3	+4.1
750	4.8	−0.0	0.8	+3.8	9.2	+0.9	−3.1	+3.4	8.7	−0.6	1.6	+3.8
1,000	5.2	−0.1	0.9	+3.1	8.6	+0.7	−2.7	+2.9	8.7	−0.5	1.0	+3.4
1,250	5.2	−0.2	0.6	+2.4	8.0	+0.7	−2.7	+2.4	8.6	−0.2	0.6	+3.1
1,500	5.0	−0.1	0.5	+2.5	7.2	+0.8	−3.1	+2.1	8.6	+.4	0.1	+2.8
2,000	3.9	+0.4	−1.5	+2.0	5.7	+0.9	−5.1	+1.5	7.8	+1.2	−1.2	+2.8
2,500	2.3	+0.9	−4.2	+1.6	4.7	+1.7	−7.5	+1.4	6.1	+1.6	−3.4	+2.6
3,000	−0.2	+0.9	−7.0	+1.3	2.4	+1.7	−10.2	+1.4	4.0	+1.9	−5.9	+2.4
3,500	−2.8	+0.9	−9.7	+1.2	0.0	+1.5	−13.3	+1.2	2.0	+2.6	.....	.....
4,000	−5.8	+0.8	−11.7	+1.9	−3.3	+1.3	−15.9	+1.5	−0.4	+2.9	.....	.....
4,500	−9.4	+0.2	.....	.....	.....	.....	−16.9	+3.0	−3.1	+2.5	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	−6.0	+2.2	.....	.....

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1923*—Continued.

RELATIVE HUMIDITY (%).

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale N. Dak. (444 m.)		Groesbeck, ex. (141 m.)		Royal Center. Ind. (225 m.)	
	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 9-yr. mean.	Mean.	Departure from 3-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 6-yr. mean.
Surface	75	+4	75	−3	76	+1	72	−9	84	+9	81	+2
250	75	+4	.....	.....	76	+2	.....	.....	83	+10	80	+1
500	68	+3	69	−5	73	+4	70	−9	80	+11	75	0
750	62	+2	61	−6	72	+6	59	−12	77	+12	71	+1
1,000	54	+2	56	−5	71	+7	55	−9	73	+14	67	+3
1,250	46	0	54	−2	69	+7	52	−7	69	+15	60	+2
1,500	42	0	51	−3	65	+5	49	−7	63	+13	55	+1
2,000	35	−2	46	−5	60	+5	49	−4	54	+12	49	−1
2,500	34	−2	46	−5	51	+3	48	−5	51	+14	48	−1
3,000	37	0	48	−3	48	+5	47	−6	50	+16	50	+1
3,500	37	0	50	−1	51	+7	49	−4	44	+12	.....	.....
4,000	36	−1	59	+7	53	+8	55	+3	40	+9	.....	.....
4,500	36	−1	.....	.....	.....	.....	47	+1	40	+10	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	40	+10	.....	.....

VAPOR PRESSURE (*mb.*).

Surface	7.68	+0.83	4.53	+0.71	10.51	+1.12	3.00	+0.01	11.43	+1.29	6.10	+1.21
250	7.61	+0.83	.....	.....	10.42	+1.15	.....	.....	11.00	+1.20	6.06	+1.23
500	6.58	+0.67	4.24	+0.59	9.78	+1.33	2.98	+0.03	10.14	+1.18	5.43	+1.19
750	5.85	+0.58	3.92	+0.54	9.29	+1.39	2.86	+0.08	9.48	+1.33	4.95	+1.16
1,000	5.22	+0.62	3.54	+0.36	8.63	+1.32	2.80	−0.02	8.80	+1.61	4.57	+1.14
1,250	4.46	+0.40	3.33	+0.33	7.89	+1.17	2.35	−0.14	8.20	+1.86	4.12	+1.02
1,500	4.03	+0.41	3.13	+0.33	7.29	+1.17	2.12	−0.19	7.50	+2.01	3.69	+0.87
2,000	3.04	+0.13	2.51	+0.15	5.92	+0.95	1.73	−0.20	5.89	+1.94	3.19	+0.87
2,500	2.56	+0.14	2.13	+0.11	4.75	+0.87	1.38	−0.24	4.93	+1.96	2.60	+0.67
3,000	2.33	+0.21	1.84	+0.16	4.28	+1.08	1.07	−0.22	4.15	+1.81	2.46	+0.84
3,500	2.02	+0.18	1.66	+0.28	3.99	+1.17	0.86	−0.15	3.20	+1.46	.....	.....
4,000	1.71	+0.09	1.64	+0.56	3.42	+1.14	0.73	−0.09	2.59	+1.15	.....	.....
4,500	1.40	−0.08	.....	.....	.....	.....	0.41	−0.16	2.29	+1.08	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	2.10	+1.06	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during December, 1923.*

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233 meters).				Drexel, Nebr. (396 meters).				Due West, S. C. (217 meters).				Ellendale, N. Dak. (444 meters).				Groesbeck, Tex. (141 meters).				Royal Center, Ind. (225 meters).			
	Mean.		6-year mean.		Mean.		9-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		6-year mean.		Mean.		6-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 88° W.	1.6	S. 51° W.	1.2	S. 69° W.	2.2	S. 86° W.	1.2	S. 49° W.	2.3	S. 55° W.	1.3	N. 66° W.	3.2	N. 56° W.	3.3	N. 36° W.	1.1	N. 87° W.	1.1	S. 54° W.	2.3	S. 50° W.	2.2
250	S. 86° W.	1.6	S. 45° W.	1.4	.....	.....	.....	.....	S. 47° W.	2.6	S. 53° W.	1.6	.....	.....	.....	.....	N. 59° W.	1.3	S. 68° W.	1.5	S. 47° W.	2.9	S. 49° W.	2.5
500	S. 68° W.	2.7	S. 47° W.	3.1	S. 72° W.	3.6	S. 88° W.	2.0	S. 57° W.	3.9	S. 63° W.	3.5	N. 67° W.	3.6	N. 62° W.	3.6	N. 83° W.	2.3	S. 55° W.	3.1	S. 55° W.	6.5	S. 57° W.	5.1
750	S. 67° W.	3.7	S. 51° W.	4.1	S. 89° W.	5.6	N. 78° W.	3.8	S. 59° W.	5.6	S. 70° W.	5.1	N. 62° W.	6.2	N. 60° W.	5.8	S. 78° W.	2.5	S. 54° W.	4.3	S. 64° W.	7.8	S. 66° W.	6.8
1,000	S. 81° W.	4.9	S. 64° W.	4.6	N. 86° W.	6.8	N. 77° W.	5.0	S. 64° W.	7.5	S. 76° W.	6.5	N. 62° W.	6.9	N. 58° W.	7.0	S. 81° W.	5.6	S. 56° W.	5.6	S. 76° W.	9.2	S. 78° W.	8.0
1,250	S. 81° W.	5.5	S. 78° W.	4.9	N. 77° W.	7.6	N. 76° W.	5.7	S. 65° W.	8.4	S. 75° W.	7.7	N. 66° W.	7.3	N. 58° W.	7.7	S. 79° W.	6.6	S. 63° W.	6.5	S. 85° W.	10.0	S. 83° W.	9.8
1,500	S. 79° W.	6.3	S. 81° W.	5.5	N. 81° W.	7.7	N. 78° W.	7.1	S. 70° W.	10.0	S. 83° W.	8.8	N. 65° W.	7.9	N. 59° W.	8.6	S. 74° W.	6.2	S. 65° W.	7.3	W.	10.9	S. 87° W.	10.9
2,000	S. 84° W.	5.6	S. 85° W.	6.7	N. 88° W.	9.0	N. 80° W.	8.8	S. 74° W.	11.0	S. 86° W.	10.2	N. 62° W.	9.2	N. 61° W.	9.9	S. 74° W.	7.7	S. 71° W.	8.5	N. 89° W.	13.1	N. 89° W.	12.4
2,500	S. 89° W.	8.0	N. 89° W.	9.4	N. 70° W.	9.6	N. 78° W.	11.2	S. 76° W.	10.5	N. 88° W.	11.7	N. 62° W.	10.0	N. 64° W.	11.8	S. 86° W.	9.1	S. 77° W.	9.6	N. 86° W.	14.9	N. 87° W.	13.4
3,000	S. 68° W.	9.6	N. 88° W.	11.1	N. 80° W.	12.9	N. 80° W.	13.3	S. 75° W.	10.2	N. 87° W.	14.0	N. 55° W.	11.0	N. 68° W.	13.0	S. 83° W.	11.6	S. 74° W.	11.4	S. 73° W.	11.7	S. 85° W.	13.5
3,500	S. 63° W.	10.6	S. 88° W.	11.8	N. 79° W.	13.6	N. 83° W.	15.1	S. 83° W.	14.6	W.	13.8	N. 57° W.	15.4	N. 74° W.	14.9	S. 78° W.	13.1	S. 74° W.	12.0	S. 68° W.	14.9	S. 84° W.	11.3
4,000	S. 71° W.	9.9	W.	10.4	N. 79° W.	11.2	N. 85° W.	16.5	S. 80° W.	14.0	N. 88° W.	12.7	N. 60° W.	15.2	N. 75° W.	14.7	N. 89° W.	14.4	S. 75° W.	11.5	.....	.....	.....	.....
4,500	N. 80° W.	11.3	N. 80° W.	12.4	N. 45° W.	13.0	N. 70° W.	17.6	S. 77° W.	16.0	N. 88° W.	14.0	N. 67° W.	17.8	S. 81° W.	15.8	N. 89° W.	16.3	N. 88° W.	12.0	.....	.....	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N. 45° W.	21.2	N. 89° W.	14.9	N. 81° W.	20.0	N. 83° W.	14.7	.....	.....	.....	.....

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

The outstanding feature of the weather during December, 1923, was the persistence of unusual warmth over the districts from the Rocky Mountains eastward, both in Canada and the United States.

This was brought about mainly through the large number of high-pressure areas entering the United States along the Oregon and California coasts, their slow rate of movement over the middle Plateau and Rocky Mountain regions, and their far southward drift in passing thence eastward to the Atlantic coast. This resulted in most low-pressure areas passing eastward north of the International Boundary, with resultant southerly winds over nearly all districts from the Great Plains eastward to the Atlantic coast.

Not until near the end of the month did a fully-developed anticyclone of the Alberta, or usual winter, type, overspread the country.

Late in the month pressure began to rise in Alaska reaching nearly 31 inches at Eagle, near the Arctic Circle, on the 28th and 29th, with temperatures 50° or more below zero. By the morning of the 30th this anticyclone had overspread the Canadian Northwest and was central over southern Alberta, Canada, and northern Montana, attended by severe cold, the temperature on the following morning reaching an extreme low reading of 53° below zero in Montana.

During the closing day of 1923 the anticyclone moved southeastward to the middle Plains, and by the first day of the new year its influence had extended into practically all parts of the country from the Rocky Mountains eastward, attended by the coldest weather of the month from Montana, the Dakotas and Minnesota, southward to the Rio Grande and the West Gulf coast.

As stated previously many of the cyclones of the month passed eastward over southern Canada, and as is usual in such cases the storms were mainly unimportant in their effect upon the weather of the United States as to precipitation, but they did induce relatively warm southerly winds far to the northward of their usual winter limits.

The first important cyclone of the month appeared in the far Southwest early in the month, and moving eastward gave mostly light precipitation over the southern mountain and Great Plains districts, reaching the lower Mississippi Valley by the morning of the 4th, at which time rain had become heavy near the center. During the following two or three days the storm moved slowly toward the lower Lakes and St. Lawrence Valley, increasing greatly in severity and attended by precipitation, mostly rain, over practically all districts from the Mississippi River eastward. Heavy rains occurred during this storm over many portions of the Gulf States, Ohio Valley, and Atlantic coast States, particularly in southern New England.

A cyclone, indifferently outlined, appears to have moved from the far West to the southern Plains by the morning of the 9th and to the west Gulf coast during the following 48 hours, attended by local rains or snows. Immediately following this another storm moved into southern Arizona and during the 10th and 11th overspread the southern mountain and Plateau States, attended by unusually heavy snow and high winds over New Mexico and portions of adjacent States. Drifting snow completely tied up automobile traffic, nullified railroad schedules, and cold weather over the same districts immediately following caused a number of deaths from freezing and much suffering to automobilists and others unable to reach shelter.

The middle portion of the month was mainly free from stormy conditions, but beginning about the 20th moderately low pressure developed in the far Southwest and extending northeasterly toward the Great Lakes gave more or less scattered precipitation over extensive areas to the eastward during the first half of the last decade. The amounts of precipitation were mostly small, however, save over the Gulf States and Ohio Valley where, toward the end of the period, they were more general and frequently heavy.

A moderately well-defined cyclone entered the far Northwest on Christmas Day, and with more or less definite character moved to the lower Missouri Valley by the morning of the 27th and thence to the St. Lawrence Valley and Canadian Maritime Provinces by the 29th. This was likewise attended by widely scattered precipitation, though mostly light, with some snow over the more northern districts.

Immediately preceding the main anticyclone of the month, low pressure developed over Colorado and vicin-

ity, and over the middle Mississippi Valley, immediately to the southward and southeastward of the cold polar front advancing southward from Canada. That portion to the southward was apparently overcome and dissipated by the rapidly advancing anticyclone, but the storm to the southeastward moved to the eastward of the Great Lakes by the close of the year, attended by a wide area of precipitation, mostly light except in portions of the Ohio Valley, with snow over the northern districts and rains to the southward.

The average sea-level pressure for the month was highest, about 30.25 inches, over the middle Plateau and lowest, slightly less than 30 inches, along and to northward of the Canadian border. Compared with the normal, the average pressure was below as a rule over the districts east of the Rocky Mountains in both Canada and the United States, although along the South Atlantic coast there was a small area with averages slightly above. West of the Rocky Mountains the average pressure was nearly everywhere above normal. The departures both above and below normal were not excessive in any section.

Compared with the preceding month the average pressure was higher in the Southeastern States, and generally over a broad area extending from Minnesota and the Dakotas southwestward to California and Arizona. The average pressure was lower than in November from Texas northeastward to New England, and over a small area in the far Northwest, including the adjacent regions of Canada. As a rule the average pressure for December is higher than that for November over all parts of the United States, save in New England and the far Northwest.

TEMPERATURE.

As stated previously the outstanding weather feature of December, 1923, was the persistent warmth, for a winter month, over all districts of the United States and Canada to eastward of the Rocky Mountains.

From the first of the month until near the middle temperature changes were mainly small, and unusually warm weather prevailed on the whole over all districts save in portions of the Southwest and far West.

In New Mexico and adjacent States severe cold set in about the 10th, following an unusual snowstorm, and it continued cold in that district for the following two weeks. Night temperatures were at times near or below zero in the protected valleys and reached extremes of 20° or more below zero in the mountains. The average daily temperatures during this period ranged from 10° to more than 30° below normal, causing a number of deaths and much suffering among those not prepared for such unusual temperatures.

About the 13th cold weather overspread the northwestern districts, and moving eastward brought the lowest temperatures of the month over many of the States to eastward of the Mississippi River. Higher temperatures quickly followed this short cold period, and unusual warmth prevailed almost continuously in all districts, save in portions of the Southwest and far West, until near the end of the month.

On the 29th an anticyclone of marked strength, accompanied by severe cold, moved southward to the upper Missouri Valley and during the following two days advanced into the Great Plains and central valleys, and at the close of the year much of the country east of the Rocky Mountains was experiencing the coldest weather of the winter to that time.

For the month as a whole a new standard of warmth was established over portions of the Middle Atlantic States, where the averages for the month were the highest in more than 50 years. In many portions of the Mississippi Valley and to the eastward the temperature was above normal every day of the month save one or two and but for the cold wave at the end the monthly averages would have exceeded those for the same months of 1877 and 1889, the only two months of that name in the past 50 years with temperatures nearly approaching or exceeding those of December, 1923, over the districts from the Rocky Mountains eastward.

In the more western portions of the country the month as a whole was colder than normal. This was particularly true of New Mexico and portions of adjoining States, in the Yellowstone Park, and over much of the Plateau region, and in northern California, where the weather was mostly colder than normal and in some localities it was among the coldest Decembers of record.

The continued warmth permitted some vegetable growth throughout nearly the entire month, and as late as Christmas Day, and in fact even to the end of the month in the more eastern districts, hardy plants like dandelions, pansies, and others in protected places were in bloom as far north as New York and the Ohio River Valley.

The warmest periods were not confined to large areas on particular dates, but occurred on numerous dates in the different sections. They occurred about the 4th–7th over much of the Mountain, Plateau, and Pacific coast States; about the 7th–10th over the Gulf States and Ohio Valley; from the 16th–22d from the Dakotas and Nebraska eastward to New England; and even on the last day of the month, just preceding the severe cold, at points in the Middle Gulf States.

The coldest periods of the month were mainly on the 14th and 15th over the Gulf States, Ohio Valley and to the eastward, although locally in the lower Mississippi Valley the 6th and 7th were the coldest days. West of the Mississippi the lowest temperatures of the month occurred mainly on the 31st. The lowest temperature observed during the month was 53° below zero on the 31st at Kinread in north-central Montana. At Cheyenne, Wyo., the lowest temperature, −28° on the 31st, was within a fraction of a degree the coldest ever observed at that place in December, and a minimum temperature of −39° at Yellowstone Park was the lowest ever observed in December at that place in a period of 35 years.

PRECIPITATION.

Considering the country as a whole, it was about evenly divided between regions having an excess of precipitation and those having a deficiency.

In the main, precipitation was above the normal over the Southern States from Arizona to Georgia, in the Ohio and portions of the middle Mississippi Valleys, over the lower Lake region, and thence eastward over Pennsylvania and New York to southern New England, and in a few other small and widely scattered areas. In portions of the Ohio Valley it was the wettest December in 70 years, and locally in Texas the precipitation for the month was the greatest of record for December, and in portions of Arizona and New Mexico there was some unusually heavy precipitation for a winter month. On the other hand precipitation was less than normal, and in some sections scanty, over the Atlantic Coast States from Virginia to Florida, from the upper Lakes westward, and generally over the Plateau and Pacific Coast

States. At points in northern California it was among the driest Decembers of record, and that State as a whole was unusually dry.

In Florida the precipitation was usually deficient to a considerable extent, particularly in the southern portions where drought, more or less severe, had prevailed since the second decade of October. At Miami, the total precipitation from October 21 to December 31 amounted to only 9 per cent of the normal for the period. This lack of precipitation, however, was beneficial rather than harmful in portions of the Everglades, permitting the low ground to dry out sufficiently for truckers to begin operations.

SNOWFALL.

The snowfall was almost as great as in any previous December over New Mexico, principally owing to the vigorous snowstorm which reached most of that State and considerable parts of adjoining States about the 10th. This snow blocked railway and highway traffic on most of the important roads. A few of the higher portions of the Northwest and part of the upper Mississippi Valley had somewhat more snowfall than the December average.

On the whole, the country had considerably less snow than usually comes at this season, and this was notably true of California and Nevada and of the States just north of the Ohio River. The Lake region and the Northeast, which are the snowiest districts of the eastern half, had less than normal, as did the northern Plains, and in these areas, as well as in the upper Mississippi Valley, most of the snow that occurred was during the final week. In the northwestern districts also the greater part of the snow came between Christmas and New Year's Day. As a result of these falls late in the month, the depth on ground when the month ended was not far from the average December condition in most portions of the country, but there was a serious shortage in the California mountains and most of the ground was bare from Illinois eastward to New Jersey and southeastern New York.

Chart VII indicates the distribution of the month's snowfall, and the inset chart shows the depths that remained on the 31st.

RELATIVE HUMIDITY.

Over most portions of California and in the adjacent parts of Nevada the general dryness of the month is indicated by the average relative humidity, which ranged from 5 to nearly 20 per cent less than normal. In Arizona, however, and thence eastward over the Gulf and South Atlantic States the relative humidity was everywhere above normal, and decidedly so in the more western portions. In other districts the relative humidity was not materially at variance with normal conditions.

SEVERE LOCAL STORMS, DECEMBER, 1923.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Puget Sound, Wash. (near Friday Harbor).	5	P. m.				Gale	Steamer foundered and crew of 15 believed lost.	Star (Seattle, Wash.).
Oregon coast	5-6					Wind and rain	Considerable property damage. Communication and traffic interrupted.	Telegram (Portland, Oreg.).
Northern Idaho and northeastern Washington.	5-6					Wind, rain, and snow.	Telephone poles and trees blown down; traffic tied up and many towns isolated.	Chronicle (Spokane, Wash.).
Binghamton, N. Y.	6					Wind	Limbs blown from trees, electric light poles, windows, and globes broken; other property damage.	Press (Binghamton, N. Y.).
New Mexico (greater portion of).	10-11			14	$200,000	Heavy snowstorm followed by severe cold.	Some livestock lost and traffic tied up. A number of persons were frozen to death.	Official, U. S. Weather Bureau.
Coos Bay, Oreg.	16			9		Wind	Steamer wrecked	Roseburg News Review (Oregon).
Washington and Oregon coasts.	25					High winds	Considerable damage to roofs, plate-glass windows, telephones, wires and poles. Shipping delayed.	Official, U. S. Weather Bureau Bulletin (San Francisco, Calif.).

STORM AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

Storm warnings were issued in connection with five storms for the Middle Atlantic and North Atlantic coast and all were fully verified, except the warnings issued on the night of the 30th. The first warnings of the month were displayed the night of the 4th, at which time a disturbance of considerable intensity was central over Kentucky and moving northeastward. This storm moved very slowly during the ensuing 36 hours, but it increased in both area and intensity. There were gales along the entire seaboard from Cape Hatteras northward, and the highest velocity reported was 60 miles an hour from the southeast at Atlantic City, N. J.

The next storm of importance to cross the country was central over northern Ontario on the morning of the 13th, and a trough of low pressure extended thence southward to the Gulf coast. Southwest storm warnings were ordered displayed at all stations from Cape Hatteras northward and gales were general during the afternoon and night of the 13th. A maximum wind of 60 miles an hour from the south occurred at Atlantic City, N. J., and the same velocity from the north at Cape Henry, Va.

The next warnings were issued for the coast from Delaware Breakwater northward in connection with a disturbance that moved rapidly eastward from Ontario to Nova Scotia during the 16th–17th. The highest wind velocity reported was 56 miles an hour from the northwest at Block Island, R. I.

A disturbance that was central over Iowa on the morning of the 27th moved rapidly east-northeastward to Nova Scotia and Newfoundland during the next two days. It increased greatly in intensity and was attended by gales almost generally along the coast from Wil-

mington, N. C., northward, the highest velocity being 68 miles an hour from the northwest at New York City. Warnings were displayed well in advance of this storm.

The last storm warnings of the month were displayed from Cape Hatteras northward in advance of the disturbance that was central over Illinois the evening of the 30th and moved northeastward with increasing intensity over the southern Lake region and the St. Lawrence valley. The maximum wind velocity reported was 56 miles an hour from the northwest at New York City.

Cold wave warnings.—December was an unusually mild month in the Washington Forecast District. No cold-wave warnings were issued, except for portions of northern New England and northern New York, until near the close of the month. Warnings were issued for practically the entire district, except southern and central Florida and the Atlantic States north of Maryland during the last two days of the month, well in advance of the cold wave that swept rapidly southeastward from the Canadian Northwest over the Plains States and the Missouri and upper Mississippi valleys. However, the cold wave lost much of its intensity in the sections farther east and south and the warnings were fully verified only in Kentucky, Tennessee, and the interior of the east Gulf States.

Frost warnings were issued for portions of the South Atlantic and east Gulf coasts and Florida on the 5th, 6th, 13th, 14th, 16th, 23d, 24th, and 25th.—*Chas. L. Mitchell.*

CHICAGO FORECAST DISTRICT.

The month was warm throughout practically the entire forecast district, and precipitation was deficient, except in the Ohio Valley. There was very little snowfall, except in the northern and eastern portions of the Great Lakes region.

Cold wave warnings.—The only cold wave of the entire month pushed southeastward from Alaska to the Canadian Northwest Provinces by December 28, and this steadily moved southward and eastward over the entire Chicago district. Warnings were issued from one to three days in advance of the area of low temperature. The cold wave finally culminated in the first week of January in a period of lowest minima registered within a decade or more at many points.

Livestock warnings.—Livestock warnings were issued for the western ranges during the closing week of the month in advance of the severe cold wave, and press dispatches indicate that, because of these warnings, all exposed cattle were driven to points of shelter.

Storm warnings.—The storm-warning season terminated on December 15 on Lake Superior and on December 18 on the balance of the Great Lakes. Until the close of the season the Great Lakes were exceptionally free from storms of great violence. Warnings were issued for four different storms, with advices for strong winds, as the disturbances moved across the Great Lakes, and so far as known no loss was experienced by vessel interests.

Following the formal close of navigation, winter service was mantained upon Lake Michigan. The storm which ushered in the cold wave at the close of the month was accompanied by strong winds, and advices well in advance were sent to the open ports on the Lake.

Warnings to banana shippers.—A special warning service as an aid to the protection of bananas in transit was begun during the month, and advices were sent to selected points in the Middle West whenever warranted by conditions.

Special forecasts.—We were requested by Mr. S. B. Fracker, State entomologist, Department of Agriculture, Madison, Wis., to issue a special forecast for certain points in Wisconsin whenever a temperature of minus 10° or lower was expected, for use in connection with tests being made with weevil-infested alfalfa. Special forecasts were sent on two dates, December 29 and 31, and apparently were highly satisfactory, as shown by the following excerpt from letter received from the Wisconsin Department of Agriculture:

> I wish to thank you for the telegrams regarding low temperatures received from your office, signed by Mr. Donnel. They were of great value, as they enabled us to get in touch with the owners of the supposedly infested alfalfa and arrange for the exposure of the hay.
>
> —*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Severe weather conditions were lacking except on December 30 to January 1, when an area of high pressure moved southward behind an east-west trough, dividing the trough after causing it to assume a crescent shape. Unusually cold weather resulted in the interior sections and a "norther" on the Texas coast. Cold-wave warnings were issued well in advance of the low temperatures attending this anticyclone and were verified except in the coast sections of Louisiana and in the vicinity of El Paso, Tex. Northwest storm warnings were displayed on the 31st for strong northerly winds on the Texas and Louisiana coasts and moderate to fresh gales on the Texas coast. Winds occurred as forecast on the Texas and western Louisiana coasts but were weaker on the eastern Louisiana coast, as the pressure gradient diminished with eastward movement of the high pressure.

Small-craft warnings, displayed on the Texas coast on the 7th and 13th, were justified. "Norther" warnings were issued for Tampico, Mexico, on the 13th and 31st.

Frost or low-temperature warnings were issued for portions of the district on the 4th, 5th, 6th, 10th, 13th, 14th, 16th, 23d, and 24th, and were verified except where cloudiness prevented frost in the extreme southern sections on the 17th, 24th, and 25th.

Warnings were issued on the 10th, 29th, 30th, and 31st for livestock interests in portions of the district and were justified. A blizzard developed in West Texas on the 10th and continued into the 11th, with temperatures well below freezing in the northern and western portions. Fire-weather warnings were issued on the 7th for forested areas in Arkansas, Oklahoma, and Texas, and were also justified.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

On the 7th, when a LOW of unusual energy moved from Alberta to the northwestern portion of the Lake region, a secondary storm of great intensity developed over southeastern Wyoming and eastern Colorado, the center of which advanced southwestward to northeastern Arizona by the morning of the 8th and thence southeastward to Texas by the night of the 8th–9th. On the morning of the 8th, warnings of a moderate cold wave were issued for southwestern Colorado and extreme northwestern New Mexico "to-night" and for southeastern New Mexico the following day, Sunday, together with livestock warnings for southwestern Colorado and northwestern New Mexico. Warnings of a moderate cold wave in southeastern New Mexico were repeated at 8 p. m. of the 8th.

The cold-wave warning was fully verified in southwestern Colorado and northwestern New Mexico. While

the fall at Roswell amounted to 22° during the 24 hours ending at 8 p. m. Sunday, the minimum temperature on Monday morning was 28° or 8° above the verifying limit. Snow fell in northern New Mexico and eastern Arizona on the 8th–11th, with rain, turning to heavy snow, in extreme eastern and southern New Mexico on the night of the 9th–10th, the snow continuing through the 11th. Gales prevailed in central and western New Mexico on the 10th and 11th. According to newspaper reports, 11 persons lost their lives in northern New Mexico as a result of the storm, and hundreds of automobile tourists were unable to proceed across the northwestern portion of that State on account of the heavy snow.

Another storm began to develop over the southern Rocky Mountain Plateau on the 18th and was central over southern Nevada on the morning of the 19th. On the morning of the 20th, when the center was over northern Arizona, warnings of a moderate cold wave and livestock warnings were issued for southwestern Colorado, extreme northwestern New Mexico, north-central and northeastern Arizona, and southern Utah. On account of a decrease in intensity of the LOW, the cold-wave warning was verified in north-central and northeastern Arizona, only. Snow fell in all of the sections specified throughout the 20th and continued in northern New Mexico and southwestern Colorado until the night of the 21st–22nd.

Warnings of a moderate cold wave were issued on the evening of the 26th for northern and eastern Colorado, and on the morning of the 27th for Colorado, northern New Mexico, northern and central Arizona, and south-eastern Utah, because of the southeastward movement of a LOW of considerable intensity which was central on the evening of the 26th over eastern Colorado and which on the morning of the 27th extended from the upper Lake region southwestward to northern Arizona, with the principal center over southern Iowa. Owing to the failure of the western extremity of the barometric trough to advance southward, and because of the development of a secondary storm over eastern Colorado on the 27th–28th, the warnings were not verified, although the temperature fell sharply on the western slope of Colorado.

During the 27th–29th a disturbance of decided intensity advanced southeastward from Alaska, with its center on the morning of the last-named date over Wyoming, while an area of high pressure, attended by a severe cold wave, occupied the extreme northeastern Rocky Mountain slope. Warnings of a severe cold wave and livestock warnings were issued for eastern Colorado on the morning of the 29th and extended to north-eastern New Mexico at 2 p. m. of the same day. Warnings of a severe cold wave in eastern and central Colorado and northeastern New Mexico were repeated on the evening of the 29th, and on the morning of the 30th these were extended to include southeastern New Mexico. Warnings of a moderate cold wave were also issued on the morning of the 30th for western Colorado, north-western New Mexico, northeastern Arizona, and south-eastern Utah, together with livestock warnings for south-western Colorado, northwestern New Mexico, north-eastern Arizona, and southeastern Utah. The warning of a severe cold wave in southeastern New Mexico was repeated on the evening of the 30th, followed on the morning of the 31st by a further warning of a moderate cold wave in the same section.

These warnings were completely verified, except that the fall in temperature at Roswell between the mornings of December 31 and January 1 amounted to but 14°, with a minimum of 14°. Temperatures below zero extended to northeastern Colorado on the morning of the 30th and to all of southern Colorado and extreme northern New Mexico on the morning of the 31st. The cold wave was preceded or accompanied by snow in about all portions of the district except extreme southern New Mexico and southern Arizona, with heavy snow during the 30th in southwestern Colorado and north-eastern Arizona.

A cold wave, without warning, occurred in north-central Colorado on the 13th, due to the eastward movement of a secondary depression which was central over the southeastern portion of the State on the morning of that date, and to the rapid southeastward advance of a HIGH from the north Pacific slope. Local cold waves, also without warning, occurred at Roswell and Durango on the 23d.

Freezing temperatures were forcast for south-central Arizona on the 9th and 12th and for southeastern Arizona on the 13th and 31st. Warnings of heavy frost were issued for south-central Arizona on the 4th, 5th, 6th, and 23d; for south-central and southwest Arizona on the 9th and 12th; for southwestern Arizona on the 13th and 31st; for southern Arizona on the 20th, 21st, 22d, 25th, and 27th.

The temperature failed to reach the freezing point in the sections mentioned on the mornings of December 10 and 14 and January 31. As a rule, the frost warnings issued were verified by temperatures at which frost might be expected to occur.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

Although December was more stormy than usual in the north portion of the district, the rainfall was unusually light in the California valleys, and there was at the close of the month a marked deficiency in the amount of snow in the Sierra Nevada Mountains. Storms moved with considerable regularity across the northern boundary of Washington and Idaho, but only a small one entered the United States south of the Columbia River, and that was not till the next to the last day of the month. The most severe storms occurred on the 6th, with a maximum wind velocity of 84 miles from the south at North Head; 10th–11th, maximum wind Nelo city 76 miles south at Talovsh Island; 18th, maximum wind 80 miles south at North Head; and on the 25th, with a maximum wind velocity of 72 miles from the southwest at North Head. This Christmas storm also caused a maximum wind velocity of 68 miles from the south at Seattle, which is one of the most, if not the most severe wind ever experienced in that city. Storm warnings were issued for one or more places in the district on 17 days and in all cases well ahead of the occurrence of the high winds.

Although frost formed frequently in California and it was necessary to issue frost warnings on no less than 18 days, the damage done by them was not great, largely on account of the protective measures taken by the growers to prevent injury. A cold-wave warning was issued on the morning of the 30th to cover places in eastern Oregon, eastern Washington and Idaho. The temperature eventually reached the zero mark in these localities, but not soon enough to completely verify the forecast.

The stormy conditions in the north and the lack of precipitation in the south were due to presistent low pressure over Bering Sea and the Aleutian Islands, which made the northern track for storms the most feasible to take in their eastward movement.—*E. A. Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

Reference to the flood table following this report will disclose the fact that floods were quite numerous, and of wide distribution as well, east of the Rocky Mountains. It will also be noted that none of the floods was serious, neither as to stage, duration, nor extent, and that the greater number occured about the middle and near the close of the month. The somewhat severe Ohio River flood of early January, 1924, set in in full force on the first day of that month, following the heavy and general rains and high temperatures of the previous day, although the river from Evansville, Ind., to Shawneetown, Ill., had already passed the flood stage after a slow and steady rise caused by the rather frequent and substantial rains from December 13 to 24, inclusive. A report on the floods in the Ohio River and its tributaries will appear in the MONTHLY WEATHER REVIEW for January, 1924.

The only flood in the Atlantic States occurred in the Santee River. It was inconsequential and was accurately forecast.

There were no floods in the Alabama River, nor in its tributaries, but after the heavy rains of December 4 the lower Tombigbee River was above the flood stage from December 6 until about the end of the month. The crest stage at Demopolis, Ala., was 43.8 feet, or 4.8 feet above the flood stage, on December 10, with secondary crests of 42.9 and 43.7 feet on December 18 and 26, respectively. Warnings were issued when necessary, beginning with December 5. Losses reported did not exceed $2,000.

There were moderate floods in the Pearl River of Mississippi during the third week of the month that were also forecast, as well as three equally moderate crests in the West Pearl River of Louisiana during the first half of the month. Total losses reported were $6,000, and the value of property saved through the warnings, $3,000, not including the value of livestock saved for which no estimate could be obtained.

Moderate rains over the upper Wabash Valley of Indiana during the day and night of December 4 resulted in some local flood-stages over that section, and a general rise a little later throughout the Valley. Heavier and more general rains on December 12 and 13 created general flood conditions that also extended over the greater portion of the lower White River Valley and continued at the close of the month in the lower White and lower Wabash Rivers. Timely warnings were issued frequently but considerable damage was done. In the lower Wabash Valley about 2,000 acres of unhusked soft corn, valued at $40,000, were lost and other reported crop losses amounted to $24,000. Damage to levees was approximately $25,000. The value of property saved through the warnings was $42,000, chiefly in crops that could be moved.

Local floods in the interior rivers of southern Ohio and in the Illinois River of Illinois were unimportant.

On account of heavy rains of December 12 and 13, a moderate flood prevailed in the extreme lower Neosho River of Oklahoma and in the Arkansas River from Webbers Falls, Okla., eastward. The crest stage at Fort Smith, Ark., on December 15 was 3 feet above flood stage of 22 feet. Otherwise flood stages were not general, although the damage done was considerable, notwithstanding the early dissemination of the flood warnings. In the Fort Smith District the reported losses were, real property, $25,000; suspension of business, $18,000, and prospective crops only $5,000, although about 12,000 acres of farm lands were overflowed. Value of property saved through the flood warnings, $5,000. Figures for the Little Rock, Ark., district were not available, but all stock and most of the crops were removed in time. However, some fields of corn were lost, and the State Dairy Farm suffered great loss by reason of caving banks.

The rains from December 10 to 13, inclusive, were equally heavy south of the Arkansas Valley with resultant general floods in the Red River and the rivers of Texas from the Guadalupe eastward. The floods were not severe, except in the upper Trinity River of Texas, and they were well forecast as a rule.

In the vicinity of Shreveport, La., caving banks caused a loss of probably more than $100,000, but elsewhere in the Red River Valley losses were small. No other figures were available, but in the Sulphur River district of Texas damage to levees, fences and roads was estimated at $3,400, while the value of property saved through the warnings was given as $15,000. In the Brazos and Trinity Valleys losses were small, owing to the fact that crops had been removed, and only $70,000 were reported, of which $33,500 was due to suspension of business. Some cattle and hogs were lost notwithstanding the warnings, but the value of property saved was reported as $125,000 plus a large amount of livestock. In the Guadalupe Valley all stock was removed from the lowlands and there were no losses.

There were no other floods except some minor ones in the Gila and Salt Rivers of Arizona on December 28, the Willamette River at Eugene, Oreg., on December 7 and the Santiam River of Oregon on December 7 and 29. No reports on these latter floods were received.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Santee:	*Feet.*			*Feet.*	
Rimini, S. C.	12	8	11	13.6	11
		20	22	13.3	21
Ferguson, S. C.	12	11	12	12.3	11
		21	25	12.5	22–25
Broad: Carlton, Ga.	11	5	5	11.9	5
EAST GULF DRAINAGE.					
Tombigbee: Lock 4, Demopolis, Ala.	39	6	30	43.8	10
Pearl:					
Jackson, Miss.	20	15	20	20.6	18
		22	29	22.3	25
Columbia, Miss.	18	25	26	18.8	25
West Pearl: Pearl River, La.	13	2	7	14.7	4
		9	12	14.5	10
		14	(1)	15.7	27
MISSISSIPPI DRAINAGE.					
Ohio:					
Evansville, Ind.	35	30	(1)	.....	.....
Dam 48, Cypress, Ind.	35	15	19	37.0	17
		24	(1)		
Shawneetown, Ill.	35	28	(1)	.....	.....
Little Kanawha: Glenville, W. Va.	23	31	(1)	.....	.....
Walhonding: Walhonding, Ohio	8	14	14	9.8	14
		23	23	8.6	23
Scioto: Circleville, Ohio	10	15	15	13.2	15
		23	25	12.8	24
Green:					
Lock 4, Woodbury, Ky.	33	25	25	33.8	25
Lock 2, Rumsey, Ky.	34	27	28	34.6	28
Wabash:					
La Fayette, Ind.	11	6	8	15.2	7
		14	17	17.5	15
		22	26	14.7	24–25
Terre Haute, Ind.	16	17	20	16.8	19
Vincennes, Ind.	14	21	26	15.4	23
Mount Carmel, Ill.	15	12	(1)	21.3	23
White: Decker, Ind.	18	15	(1)	20.9	22
White, East Fork: Seymour, Ind.	10	14	16	11.5	15
		23	23	11.0	23
White, West Fork:					
Edwardsport, Ind.	14	10	29	17.6	24
Elliston, Ind.	19	11	11	19.5	11
		14	18	22.7	16–17
		23	24	19.3	24

[1] Continued at end of month.

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
MISSISSIPPI.	*Feet.*			*Feet.*	
Illinois:					
Peru, Ill.	14	14	(1)	15.1	17-18
Henry, Ill.	7	13	(1)	8.9	29-31
Beardstown, Ill.	12	14	(1)	14.9	26-27
Meramec: Pacific, Mo.	11	13	16	14.4	16
Bourbeuse: Union, Mo.	10	15	15	13.6	15
St. Francis: Marked Tree, Ark.	17	23	(1)	.....	.....
Arkansas:					
Fort Smith, Ark.	22	14	16	25.0	15
Dardanelle, Ark.	20	14	17	22.0	16
Neosho: Fort Gibson, Okla.	22	14	14	22.0	14
Petit Jean: Danville, Ark.	20	13	17	23.3	15
Cache: Patterson, Ark.	9	17	(1)	.....	.....
Red:					
Index, Tex.	27	18	18	27.0	18
Fulton, Ark.	28	16	27	31.4	19
Alexandria, La.	36	26	(1)	.....	.....
Sulphur:					
Ringo Crossing, Tex.	20	12	18	25.4	14
	.....	21	26	22.9	23
Finley, Tex.	24	16	31	27.8	18
Cypress: Jefferson, Tex.	18	31	(1)	.....	.....
Ouachita: Camden, Ark.	30	17	18	30.6	18
WEST GULF DRAINAGE.					
Sabine:					
Logansport, La.	25	23	(1)	28.2	26-27
Bon Wier, Tex.	20	23	29	21.1	25-26
Orange, Tex.	4	23	(1)	5.7	25
Neches:					
Rockland, Tex.	22	26	26	22.0	26
Beaumont, Tex.	7	22	(1)	10.4	25
Trinity:					
Dallas, Tex.	25	12	20	38.1	15
Trinidad, Tex.	28	14	27	38.5	21
Long Lake, Tex.	40	19	28	41.5	25-26
Liberty, Tex.	25	22	(1)	27.5	28-30
Elm Fork: Carrollton, Tex.	7	13	16	12.8	14
Brazos, Little: Little River, Tex.	30	13	13	37.0	13
Gaudalupe:					
Gonzales, Tex.	22	14	15	23.6	15
Victoria, Tex.	16	15	24	21.7	22
COLORADO DRAINAGE.					
Gila:					
Kelvin, Ariz.	5	28	(1)	6.4	29
Gila Bend, Ariz.	5	28	28	6.0	28
Salt: Phoenix, Ariz.	5	27	28	9.6	27
PACIFIC DRAINAGE.					
Willamette: Eugene, Oreg.	10	7	7	12.0	7
Santiam: Jefferson, Oreg.	10	7	7	11.0	7
		29	29	12.0	29

[1] Continued at end of month.

MEAN LAKE LEVELS DURING DECEMBER, 1923.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Jan. 7, 1924.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1] Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during December, 1923:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.78	578.80	571.29	244.47
Above or below—				
Mean stage of November, 1923	−0.25	−0.26	+0.29	+0.13
Mean stage of December, 1922	−0.24	−0.38	+0.18	−0.17
Average stage for December last 10 years	−0.58	−1.27	−0.49	−0.91
Highest recorded December stage	−1.35	−3.78	−2.24	−3.14
Lowest recorded December stage	+0.58	−0.20	+0.43	+1.04
Average relation of the December level to—				
November level	.....	−0.2	−0.2	−0.2
January level	.....	+0.1	.....	−0.1

[1] Lake St. Clair's level: In December, 1923, 573.97 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS. DECEMBER, 1923.

By J. B. KINCER.

The month, as a whole, was favorable for agricultural interests in most sections of the country, though it was generally unfavorable for farm work in the Southern States because of frequent rains and wet soil, while outdoor operations were hindered considerably by the same cause in the Ohio Valley area. Unusually mild, open weather was experienced in the central and northern Great Plains, and seasonal farm operations made good progress.

The principal winter-wheat area was bare of snow throughout almost the entire month, but the weather was not severe enough to be materially harmful until near the close when the first severe cold wave of the season overspread the Northern and Central States. Grain fields were generally protected by snow cover during the prevalence of this cold wave in the Northern, Western, and Northwestern States, including most of the wheat fields in Kansas, but some slight injury was reported from freezing locally in the Ohio Valley States. Earlier in the month there was some damage by overflow in some parts of the Ohio Valley.

Corn fields were soft and muddy during much of the month in the East-Central States, and husking was considerably delayed, especially in parts of the Ohio Valley. Husking made good progress, under favorable weather conditions, in the Great Plains and more northwestern States. Conditions were rather unfavorable for completing cotton picking in the western portions of the belt, but this work made good progress in the far Southwest, including the Imperial Valley of California.

A cool wave near the middle of the month damaged truck crops some in Texas and, at the same time, some slight harm was done to tender vegetation in central Gulf districts. Rain during the first half of the month benefited truck in the Gulf States, but drier weather and more sunshine were needed the latter part.

The month was unusually favorable for stock in the great western grazing districts until near its close when stormy weather and a severe cold wave prevailed. This storm mostly covered the range with snow, and the low temperatures unfavorably affected stock in the central and northern Rocky Mountain districts. The snow was beneficial in Montana, however, in replenishing stock water on the range, while the weather was generally helpful to stock interests east of the Plains area. A severe drought prevailed in California which unfavorably affected the range and livestock.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, December, 1923.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	54.6	+8.0	Evergreen	83	31	Florence	22	[2] 14	5.39	+0.50	Madison	9.28	Union Springs	1.78
Alaska														
Arizona	42.8	−0.4	Marinette	81	10	Winslow	−10	13	3.00	+1.82	Pinal Ranch	9.41	Lees Ferry	0.12
Arkansas	49.1	+7.0	Texarkana	80	8	3 stations	9	31	6.24	+2.15	Magnolia	11.80	Mountain Home	3.38
California	45.8	−0.7	Corona	84	16	2 stations	4	[2] 10	1.77	−2.20	Crescent City	7.99	3 stations	0.00
Colorado	25.5	0.0	Holly	81	6	Dillon	−32	10	1.06	+0.02	Cumbres	3.80	Rocky Ford	T.
Florida	64.7	+5.3	2 stations	90	[2] 1	Arcadia	26	26	1.45	−1.53	Hypoluxo	4.84	Allapattah	0.14
Georgia	54.4	+7.3	3 stations	82	[2] 11	Clayton	14	15	4.12	−0.11	Gillsville	7.93	Waycross	1.26
Hawaii	69.7	−0.1	2 stations	90	2	Waimea	46	13	16.86	+7.25	Honomu	71.84	Puulehua	0.70
Idaho	25.2	−0.5	Parma	60	6	Driggs	−31	31	1.70	−0.23	Wallace	7.34	Monteview	0.19
Illinois	40.6	+10.4	Sparta	75	27	Peoria	−2	31	3.67	+1.53	New Burnside	7.55	Elgin	1.05
Indiana	41.6	+9.7	4 stations	69	[2] 8	3 stations	10	[2] 14	5.75	+3.01	Bedford	8.91	Whiting	1.43
Iowa	33.5	+9.6	Oakland	68	17	Sanborn	−21	31	0.76	−0.46	Mount Pleasant	2.22	2 stations	T.
Kansas	35.8	+4.2	Liberal	80	7	St. Francis	−13	31	0.67	−0.23	Columbus	3.61	do	0.10
Kentucky	46.6	+9.5	Jackson	75	31	2 stations	8	14	6.60	+2.66	Junction City	9.73	Pikeville	4.06
Louisiana	58.6	+6.8	2 stations	82	[2] 9	Kelly (near)	25	6	7.48	+2.30	Alexandria	14.95	Houma	2.13
Maryland-Delaware	43.7	+9.1	do	72	13	Oakland, Md	2	15	3.55	+0.19	Grantsville, Md	6.17	Solomons, Md	1.47
Michigan	33.5	+8.8	Lapeer	62	21	2 stations	−3	[2] 14	2.24	+0.20	Howell	5.05	St. James	0.59
Minnesota	25.2	+10.5	Faribault	69	20	Roseau	−31	[2] 30	0.54	−0.21	Zumbrota	1.82	Hallock	0.05
Mississippi	55.1	+7.4	Edinburg	81	31	3 stations	23	[2] 7	7.52	+2.08	Anguilla	13.80	Pearlington	3.01
Missouri	41.0	+7.1	Hollister	82	9	Conception	−4	31	3.06	+1.03	Parma	6.33	Conception	0.25
Montana	25.0	+2.3	2 stations	66	[2] 5	Kinread	−53	31	0.96	+0.05	Heron	5.38	Medicine Lake	T.
Nebraska	31.2	+5.2	do	75	17	2 stations	−30	31	0.53	−0.19	Genoa	1.11	Western	0.02
Nevada	30.0	−2.1	Beatty	73	6	San Jacinto	−18	28	0.68	−0.28	Mahoney R. S	2.12	2 stations	0.00
New England	33.6	+7.6	Turners Falls, Mass	66	7	2 stations	−12	[2] 19	4.01	+0.66	Kingston, R. I	7.05	Burlington, Vt	1.35
New Jersey	40.8	+7.8	2 stations	69	[2] 9	do	9	15	4.14	+0.21	Little Falls	5.14	Cape May City	2.44
New Mexico	32.7	−1.4	do	76	7	do	−23	[2] 12	1.85	+0.98	Hermosa	6.94	Los Lunas	0.22
New York	35.3	+9.1	Flushing	65	21	Indian Lake	−11	30	3.39	+0.38	Scarsdale	6.43	Chazy	0.83
North Carolina	49.2	+7.7	Scotland Neck	78	22	Parker	10	15	3.01	−0.87	Andrews	7.55	Kinston	1.40
North Dakota	22.2	+9.2	Amenia	62	16	Dunseith	−36	30	0.32	−0.22	Grand Forks	0.96	Garrison	T.
Ohio	40.8	+9.8	2 stations	69	[2] 22	Summerfield	7	15	5.92	+3.17	Wilmington	10.49	Montpelier	3.58
Oklahoma	43.6	+4.2	Frederick	81	24	Hurley	−6	31	2.86	+1.04	Antlers	12.27	Mutual	0.20
Oregon	35.3	+0.4	3 stations	70	4	Madras	−12	31	3.98	−0.15	Cascade Locks	15.55	Kingman	0.24
Pennsylvania	39.6	+9.0	Gettysburg	71	21	Ebensburg	1	15	4.99	+1.54	Creekside	8.55	Scranton	2.42
Porto Rico	73.8	−0.8	3 stations	96	[2] 4	Cayey	50	3	3.27	−1.52	Rio Grande	9.63	Santa Isabel	0.07
South Carolina	52.5	+5.9	do	79	[2] 10	Clemson College	23	7	4.12	+0.70	Clemson College	6.60	Florence No. 2	1.56
South Dakota	28.1	+7.4	Colome	68	18	Ardmore	−32	31	0.33	−0.25	Redig	1.10	2 stations	T.
Tennessee	48.4	+8.5	Newport	77	9	Tazewell	−1	15	5.68	+1.11	Paris	8.79	Elizabethton	3.23
Texas	51.2	+1.7	Fort Stockton	90	9	Dalhart	−5	31	5.47	+3.31	Beaumont	16.99	Claude	0.40
Utah	26.0	−0.4	Moab	65	7	Woodruff	−28	27	0.89	−0.17	Silver Lake	5.06	2 stations	T.
Virginia	45.7	+8.9	Hopewell	76	21	2 stations	5	[2] 14	2.79	−0.61	Wise	6.96	Norfolk	0.93
Washington	34.6	+1.5	Kennewick	68	4	Snyder's Ranch	−28	31	5.23	+0.36	Forks	29.50	Lost Creek	0.28
West Virginia	43.1	+9.5	Bluefield	78	8	Cheat Bridge	0	[2] 15	5.82	+2.35	Pickens	10.96	Upper Tract	1.00
Wisconsin	30.3	+10.1	Ashland	60	19	Danbury	−18	31	1.39	+0.17	Williams Bay	2.55	Amery	0.43
Wyoming	20.8	−0.5	2 stations	68	[2] 6	Buffalo Ranch	−50	31	0.75	+0.13	Moran	3.13	Deaver	T.

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384–385.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, December, 1923.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
New England.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
							36.4	**+7.1**											**78**	**4.05**	**+0.7**										**6.8**		
Eastport	76	67	85	29.89	29.98	.00	32.2	+5.9	55	6	38	6	19	26	37	30	27	80	3.18	−0.8	17	9,376	nw.	46	ne.	28	4	5	22	7.8	9.4	6.1
Greenville, Me.	1,070	6	....	28.79	29.99	.....	26.8	.....	50	6	33	2	18	21	35	....	....	....	3.32	.....	15	.....	.....	.....	.....	.....	4	5	22	....	18.9	11.0
Portland, Me.	103	82	117	29.90	30.03	.00	34.1	+6.5	56	13	40	10	30	28	34	31	26	75	3.58	−0.1	14	6,639	nw.	36	se.	28	10	5	16	6.2	12.0	8.3
Concord	288	70	79	29.69	30.01	−.05	33.2	+6.4	61	13	41	10	30	26	29	....	....	....	3.09	−0.3	12	3,697	nw.	27	sw.	13	6	11	14	6.7	8.0	6.0
Burlington	404	11	48	29.57	30.03	−.02	31.8	+9.3	53	6	38	1	30	26	28	....	....	....	1.35	−0.3	15	9,529	s.	52	s.	13	0	11	20	8.1	7.0	3.2
Northfield	876	12	60	29.05	30.03	−.02	28.2	+7.7	58	13	36	−9	30	20	27	27	24	86	2.25	−0.5	15	5,311	s.	29	sw.	7	1	10	20	8.1	21.5	8.3
Boston	125	115	188	29.88	30.02	−.03	40.4	+7.9	62	13	47	19	18	34	25	36	32	74	4.98	+1.6	13	7,639	w.	32	w.	29	7	11	13	6.5	3.0	T
Nantucket	12	14	90	30.00	30.02	−.03	41.6	+4.9	56	9	47	26	15	36	29	39	36	86	5.19	+1.6	15	12,241	sw.	47	se.	28	5	8	18	7.0	5.8	T.
Block Island	26	11	46	29.99	30.02	−.04	41.8	+5.8	58	6	47	23	15	37	27	39	35	79	4.78	+1.0	12	15,535	nw.	48	nw.	11	9	4	18	6.6	4.1	0.0
Providence	160	215	251	29.86	30.04	−.02	39.0	+7.4	60	13	45	18	15	32	26	35	31	76	5.13	+1.2	12	9,173	nw.	58	nw.	29	10	7	14	5.9	6.1	2.1
Hartford	159	122	140	29.86	30.04	−.03	38.6	+8.8	60	20	45	20	15	32	25	34	30	75	4.84	+1.3	14	5,822	nw.	35	sw.	6	6	9	16	6.8	7.1	4.5
New Haven	106	74	153	29.93	30.05	−.02	39.8	+7.3	59	21	46	21	15	34	19	36	31	75	6.18	+2.5	15	6,865	sw.	39	sw.	6	12	5	14	5.2	7.8	1.4
Middle Atlantic States.							**43.5**	**+8.0**											**77**	**3.07**	**−0.1**										**6.0**		
Albany	97	102	115	29.94	30.04	−.04	36.4	+7.9	58	13	42	12	20	30	23	33	29	78	3.17	+0.6	14	5,831	s.	42	s.	6	11	8	12	5.8	8.1	6.0
Binghamton	871	10	84	29.06	30.02	−.07	37.0	+9.3	61	13	43	16	15	31	29	....	....	....	2.69	+0.2	16	4,743	nw.	42	sw.	6	1	8	22	8.2	7.3	2.0
New York	314	414	454	29.72	30.06	−.03	42.0	+7.0	64	13	48	24	15	36	22	37	32	72	3.78	+0.3	13	13,649	nw.	68	nw.	28	8	8	15	6.5	1.2	0.0
Harrisburg	374	94	104	29.68	30.09	−.03	41.8	+9.0	64	21	48	24	15	36	24	37	32	73	3.75	+1.1	15	4,796	nw.	38	sw.	28	9	7	15	6.6	1.1	0.0
Philadelphia	114	123	190	29.95	30.08	−.03	44.6	+8.3	65	13	50	27	15	39	23	39	34	71	4.06	+1.0	15	7,097	w.	37	sw.	6	10	9	12	6.0	1.8	0.0
Reading	325	81	98	29.71	30.07	.....	42.0	.....	61	21	48	22	15	36	23	39	36	83	4.51	+1.2	16	4,725	nw.	28	nw.	28	9	8	14	6.0	2.0	0.0
Scranton	805	111	119	29.17	30.06	−.04	38.7	+8.9	60	13	45	19	15	32	26	36	33	82	2.42	−0.2	18	5,290	s.	38	sw.	28	2	12	17	7.4	5.1	0.4
Atlantic City	52	37	172	30.02	30.08	−.02	44.6	+8.2	62	21	51	25	15	38	25	41	38	80	3.63	−0.1	12	12,420	w.	62	se.	5	12	11	8	5.2	1.5	0.0
Cape May	17	13	49	30.09	30.11	.00	45.0	+7.0	60	9	50	23	15	40	20	41	38	82	2.44	−1.3	11	6,186	nw.	34	se.	6	11	6	14	5.5	2.7	0.0
Sandy Hook	22	10	55	30.03	30.05	.....	42.6	.....	64	13	47	28	15	38	22	39	35	76	3.57	.....	13	12,134	sw.	54	w.	28	10	8	13	6.0	0.1	0.0
Trenton	190	159	183	29.85	30.06	.....	42.0	.....	64	13	48	22	15	36	24	38	34	77	3.94	+0.8	15	8,367	sw.	54	sw.	6	9	10	12	6.0	1.5	0.0
Baltimore	123	100	113	29.94	30.07	−.06	45.4	+8.2	65	13	52	24	15	39	24	40	36	76	3.88	+0.8	15	3,850	sw.	26	sw.	13	11	8	12	5.9	1.7	0.0
Washington	112	62	85	29.96	30.08	−.05	45.0	+8.4	68	21	53	22	15	37	28	40	35	74	2.80	−0.4	12	4,081	s.	30	n.	13	9	8	14	6.1	1.7	0.0
Cape Henry	18	8	54	30.08	30.10	.....	50.2	.....	73	9	58	33	19	43	29	46	43	81	2.05	−1.4	8	9,146	sw.	60	n.	14	11	8	12	5.4	T.	0.0
Lynchburg	681	153	188	29.34	30.10	−.04	47.4	+7.9	72	22	58	20	15	37	36	42	38	77	2.72	−0.6	10	5,129	w.	35	w.	28	11	7	13	5.9	0.6	0.0
Norfolk	91	170	205	30.02	30.12	−.01	51.1	+8.0	70	9	59	32	14	43	32	45	40	73	0.93	−2.6	8	10,217	s.	42	n.	14	12	11	8	5.2	T.	0.0
Richmond	144	11	52	29.95	30.11	−.03	47.6	+6.6	74	22	58	24	15	38	30	42	38	75	2.28	−0.7	9	6,099	sw.	42	sw.	6	13	7	11	5.0	1.0	0.0
Wytheville	2,304	49	55	27.69	30.12	−.03	43.0	+7.7	69	9	53	13	15	33	38	38	34	76	3.19	−0.6	12	5,219	w.	35	w.	6	10	6	15	6.1	1.6	0.0
South Atlantic States.							**54.2**	**+6.4**											**81**	**2.96**	**−0.4**										**6.2**		
Asheville	2,255	70	84	27.76	30.16	.00	46.2	+8.4	70	9	56	23	15	36	35	42	38	78	2.72	−0.4	12	6,205	se.	34	nw.	13	11	6	14	5.9	1.0	0.0
Charlotte	779	55	62	29.28	30.13	−.03	50.2	+7.2	71	28	59	25	15	42	27	46	42	78	3.33	−0.5	11	4,078	sw.	27	sw.	5	10	6	15	6.1	0.0	0.0
Hatteras	11	11	50	30.12	30.13	.00	53.8	+3.7	70	20	60	40	14	48	26	50	48	83	3.71	−1.4	11	11,209	sw.	48	nw.	14	11	8	12	5.4	0.0	0.0
Manteo	12	5	42	....	....	.....	50.6	.....	73	22	61	28	25	40	36	....	....	....	2.74	.....	4	.....	sw.	.....	.....	.....	20	4	7	....	0.0	0.0
Raleigh	376	103	110	29.72	30.13	−.02	51.0	+8.3	72	10	60	25	15	42	34	45	42	78	1.71	−1.5	9	6,253	sw.	41	sw.	6	12	7	12	5.6	T.	0.0
Wilmington	78	81	91	30.07	30.16	+.01	54.4	+5.3	74	10	63	28	15	46	35	49	47	85	3.17	0.0	9	5,759	sw.	32	w.	28	12	9	10	5.2	0.0	0.0
Charleston	48	11	92	30.11	30.16	+.01	56.9	+5.2	75	21	64	33	15	50	28	52	49	84	3.91	+0.8	10	7,507	sw.	33	n.	14	4	12	15	7.0	0.0	0.0
Columbia, S. C.	351	41	57	29.77	30.16	.00	54.1	+6.9	74	10	63	29	15	46	32	49	46	82	2.72	−0.2	9	5,861	ne.	37	sw.	5	7	10	14	6.5	0.0	0.0
Due West	711	10	55	29.38	30.17	.....	50.4	.....	72	10	59	27	7	42	31	....	....	....	5.14	.....	14	7,029	sw.	42	w.	5	5	11	15	7.4	0.0	0.0
Greenville, S. C.	1,039	113	122	29.01	30.12	.....	50.0	.....	70	31	58	27	15	42	25	46	42	79	4.59	.....	12	6,770	sw.	37	sw.	5	10	6	15	6.1	0.0	0.0
Augusta	180	62	77	29.95	30.14	−.02	55.0	+6.9	76	31	64	30	15	46	34	50	47	82	4.65	+1.2	11	4,311	s.	33	sw.	5	5	12	14	6.5	0.0	0.0
Savannah	65	150	194	30.08	30.15	.00	58.5	+6.1	77	30	67	35	15	50	27	53	50	82	2.30	−0.8	9	8,730	ne.	42	nw.	5	5	11	15	6.7	0.0	0.0
Jacksonville	43	209	245	30.10	30.15	+.01	61.8	+5.5	78	31	69	38	25	55	23	56	53	80	1.38	−1.6	9	9,323	ne.	37	w.	5	6	10	15	6.5	0.0	0.0
Florida Peninsula.							**69.9**	**+3.4**											**78**	**0.43**	**−1.6**										**4.8**		
Key West	22	10	64	30.08	30.10	+.02	72.9	+2.6	82	23	78	60	25	68	14	67	64	80	0.35	−1.5	8	7,518	e.	31	nw.	5	17	10	4	4.0	0.0	0.0
Miami	25	71	79	30.11	30.14	.....	70.6	+2.6	80	5	76	48	25	65	23	64	61	75	0.46	−1.8	12	6,128	e.	27	e.	19	13	10	8	4.7	0.0	0.0
Sand Key	23	39	72	30.08	30.12	+.04	72.2	.....	78	23	75	60	25	70	9	67	65	77	0.48	.....	8	12,071	ne.	39	se.	20	16	11	4	3.9	0.0	0.0
Tampa	35	79	87	30.11	30.15	+.03	66.3	+5.1	79	2	74	42	25	59	23	60	58	82	0.47	−1.6	3	3,960	ne.	22	sw.	5	5	15	11	5.8	0.0	0.0
East Gulf States.							**56.1**	**+6.7**											**84**	**4.96**	**+0.4**										**7.6**		
Atlanta	1,174	190	216	28.88	30.14	−.02	51.3	+6.6	71	31	58	29	14	44	31	48	46	83	5.60	+1.1	15	8,595	nw.	42	nw.	31	3	2	26	8.4	0.0	0.0
Macon	370	78	87	29.75	30.15	−.01	54.8	+8.0	79	31	63	31	7	46	31	50	47	81	3.05	−1.4	11	4,806	s.	30	nw.	13	2	6	23	8.0	0.0	0.0
Thomasville	273	49	58	29.85	30.15	.00	59.4	+6.9	79	20	68	35	25	51	29	54	51	83	2.79	−0.9	9	3,757	sw.	24	sw.	5	5	8	18	7.2	0.0	0.0
Apalachicola	36	42	49	30.10	30.14	.....	60.6	.....	75	29	66	41	25	55	20	57	55	88	2.09	.....	6	5,968	ne.	30	n.	14	8	12	11	5.6	0.0	0.0
Pensacola	56	149	185	30.07	30.13	−.02	59.5	+5.5	75	11	64	39	14	54	22	57	55	88	1.26	−2.9	13	10,420	e.	40	n.	13	4	5	22	7.7	0.0	0.0
Anniston	741	9	57	29.34	30.15	−.01	52.6	+8.4	75	30	61	27	7	45	34	....	....	....	5.82	+1.3	13	4,995	se.	27	se.	15	3	12	16	7.4	0.0	0.0
Birmingham	700	11	48	29.38	30.15	−.01	53.3	+6.0	73	31	61	28	14	46	36	49	46	80	5.30	+0.7	15	6,478	s.	37	s.	4	5	3	21	7.9	0.0	0.0
Mobile	57	125	161	30.06	30.12	−.03	58.2	+5.3	74	31	64	37	14	52	26	56	55	91	6.12	+1.6	14	8,067	s.	48	nw.	13	3	8	20	7.5	0.0	0.0
Montgomery	223	100	112	29.90	30.15	−.01	56.3	+6.9	79	31	64	34	14	49	34	52	49	81	4.60	+0.1	10	5,456	se.	34	w.	5	5	2	24	7.9	0.0	0.0
Corinth	469	6	....	....	....	.....	51.8	.....	72	30	60	24	15	43	37	....	....	....	6.24	.....	16	.....	s.	....	.....	.....	3	11	17	....	0.5	0.0
Meridian	375	85	93	29.72	30.12	−.04	55.0	+8.1	76	30	63	29	14	47	38	52	49	83	5.99	+0.8	12	4,936	sw.	30	nw.	31	5	5	21	7.7	0.0	0.0
Vicksburg	247	65	73	29.85	30.14	−.01	56.2	+6.2	75	30	63	32	14	50	36	52	50	84	9.64	+4.6	14	5,826	se.	28	nw.	31	5	2	24	8.0	0.0	0.0
New Orleans	53	76	84	30.06	30.11	−.02	60.9	+5.3	78	30	68	39	14	54	31	58	56	87	4.37	−0.1	14	5,501	s.	24	ne.	31	4	6	21	7.7	0.0	0.0
West Gulf States.							**53.5**	**+4.3**											**84**	**5.86**	**+3.0**										**7.7**		
Shreveport	249	77	93	29.83	30.11	−.02	54.9	+6.0	79	9	62	30	31	48	39	51	48	82	7.82	+3.4	15	5,396	s.	26	s.	7	7	4	20	7.2	0.0	0.0
Bentonville	1,303	11	44	.....	.....	.....	44.8	+7.3	70	9	54	9	31	36	35	....	....	....	3.79	.....	11	4,695	s.	37	s.	7	13	8	10	....	0.1	0.0
Fort Smith	457	79	94	29.59	30.08	−.05	48.2	+6.5	76	8	56	16	31	40	33	43	39	76	4.26	+1.4	12	6,523	e.	37	sw.	27	5	12	14	6.6	T.	0.0
Little Rock	357	136	144	29.70	30.09	−.05	51.2	+7.0	74	8	59	22	31	43	31	47	44	81	4.70	+0.5	16	7,200	s.	40	s.	7	5	6	20	7.5	0.0	0.0
Brownsville	57	53	61	30.00	30.06	.....	61.8	.....	78	9	68	42	15	56	33	58	57	89	2.86	.....	16	6,928	s.	29	s.	27	1	6	24	8.5	0.0	0.0
Corpus Christi	20	11	73	30.07	30.09	−.03	58.6	+2.0	77	27	64	38	14	53	29	56	54	87	5.17	+3.8	15	8,053	n.	47	n.	31	2	3	26	8.7	0.0	0.0
Dallas	512	109	117	29.54	30.10	.....	50.8	.....	80	29	58	20	31	43	41	....	....	....	6.53	.....	13	6,158	s.	32	s.	8	6	13	12	6.6	0.0	0.0
Fort Worth	670	105	114	29.46	30.08	−.04	50.7	+3.2	81	29	59	18	31	43	47	47	44	85	4.68	+3.5	12	7,030	nw.	30	s.	7	6	12	13	6.2	0.0	0.0
Galveston	54	106	114	30.04	30.10	−.02	58.8	+2.4	72	9	64	38	14	54	27	57	55	89	7.84	+4.1	13	8,915	se.	36	nw.	31	3	8	20	7.9	0.0	0.0
Groesbeck	461	11	56	29.59	30.08	.....	52.7	.....	79	9	59	25	31	46	29	....	....	....	8.45	.....	13	8,017	n.	39	sw.	7	3	6	22	8.0	0.0	0.0
Houston	138	111	121	29.93	30.08	.....	58.6	+4.1	80	9	64	32	15	53	35	....	....	....	14.38	.....	18	6,014	n.	26	nw.	12	3	4	24	8.4	0.0	0.0
Palestine	510	64	72	29.56	30.10	−.02	53.6	+3.7	79	29	60	25	31	47	41	50	48	86	8.48	+4.8	17	6,005	sw.	36	sw.	7	4	5	22	7.9	T.	0.0
Port Arthur	34	58	66	30.05	30.09	.....	58.9	.....	74	28	64	33	15	53	28	56	54	87	9.59	.....	10	7,224	s.	33	nw.	31	4	3	24	8.1	0.0	0.0
San Antonio	693	119	132	29.35	30.09	−.02	55.6	+2.5	78	30	62	32	14	49	32	51	49	81	4.29	+2.7	15	5,367	ne.	30	nw.	4	2	12	17	7.5	0.0	0.0
Taylor	583	55	63	29.49	30.11	.00	53.4	+2.8	78	9	60	27	31	47	41	....	....	....	5.54	+2.9	15	6,451	nw.	32	sw.	7	2	7	22	8.2	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, December, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F. 45.5	°F. +9.0	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 81	*In.* 5.81	*In.* +2.4		*Miles.*							*0–10* 7.3	*In.*	*In.*
Chattanooga	762	189	213	29.32	30.14	−.02	49.4	+6.1	72	31	57	25	15	42	36	45	41	76	5.09	+0.7	15	5,929	se.	36	w.	5	3	8	20	7.6	2.2	0.0
Knoxville	996	102	111	29.04	30.11	−.05	47.8	+7.5	70	9	57	21	15	38	40	45	43	87	3.72	−0.4	15	5,065	sw.	38	s.	13	4	12	15	6.9	T.	0.0
Memphis	399	76	97	29.67	30.10	−.05	51.5	+7.9	70	8	59	23	31	44	44	48	44	79	5.35	+1.0	14	6,135	se.	32	nw.	13	6	7	18	7.4	T.	0.0
Nashville	546	168	191	29.53	30.13	−.02	49.4	+8.4	69	31	58	22	14	41	45	45	41	77	4.32	+0.5	14	7,844	s.	46	nw.	31	6	5	21	7.5	3.0	0.0
Lexington	989	193	230	29.01	30.10	−.04	45.2	+8.8	65	30	53	16	15	37	42	.....	.....	.....	6.50	+3.2	16	11,678	sw.	46	sw.	27	7	4	20	7.0	2.5	0.0
Louisville	525	219	255	29.50	30.09	−.05	46.6	+9.0	67	30	55	19	31	38	45	42	38	76	5.91	+2.2	15	9,091	s.	44	s.	13	7	6	18	7.3	0.5	0.0
Evansville	431	139	175	29.62	30.10	−.03	48.6	+10.3	67	30	54	16	31	39	35	43	39	78	6.43	+2.6	14	8,516	sw.	38	w.	31	3	10	18	7.1	1.0	0.0
Indianapolis	822	194	230	29.16	30.06	−.06	42.4	+10.2	62	8	50	14	31	35	34	39	36	83	5.60	+2.6	17	9,008	s.	44	w.	31	6	8	17	7.2	1.0	T.
Royal Center	736	11	55	29.24	30.03	.....	38.2	.....	57	8	46	10	31	31	31	.....	.....	.....	5.13	.....	15	8,354	s.	39	w.	31	4	5	22	8.3	2.4	T.
Terre Haute	575	96	129	29.43	30.06	.....	43.0	.....	65	8	50	14	31	36	32	39	37	84	4.23	.....	16	7,539	s.	37	w.	31	6	5	20	7.3	T.	T.
Cincinnati	628	11	51	29.38	30.07	−.06	43.5	+10.1	64	30	52	18	14	35	38	.....	39	84	6.94	+4.0	17	5,785	sw.	34	w.	28	7	5	19	7.1	2.7	T.
Columbus	824	179	222	29.16	30.06	−.06	42.0	+10.6	60	8	49	2	14	35	35	39	37	88	6.12	+3.4	17	5,955	s.	39	w.	31	4	6	21	7.6	0.3	0.0
Dayton	899	137	173	29.08	30.06	.....	42.2	+9.1	60	8	50	20	31	35	38	39	36	83	6.84	+4.2	18	7,374	sw.	46	w.	31	7	6	18	6.9	2.9	T.
Elkins	1,947	59	67	28.00	30.12	.00	41.7	+9.2	67	13	52	7	15	31	47	37	34	83	6.95	+3.5	16	4,396	w.	34	w.	28	6	8	17	7.1	3.5	0.0
Parkersburg	638	77	84	29.42	30.09	−.05	45.2	+10.0	65	13	54	20	15	36	38	41	38	79	5.36	+2.6	17	4,394	se.	34	w.	28	7	4	20	7.2	1.0	0.0
Pittsburgh	842	353	410	29.13	30.06	−.05	43.0	+8.8	66	13	50	22	15	36	38	39	35	76	6.22	+3.5	16	8,287	sw.	49	sw.	13	3	7	21	8.0	1.0	0.0
Lower Lake Region.							37.7	+8.6										81	3.67	+0.8									7.9		
Buffalo	767	247	280	29.17	30.02	−.04	37.6	+7.8	57	13	42	23	14	33	31	35	31	79	3.00	−0.4	16	16,521	w.	80	w.	31	4	4	23	7.9	5.5	0.0
Canton	448	10	61	29.50	29.99	.....	31.7	+9.0	58	13	38	−3	30	25	37	.....	.....	.....	2.51	−1.1	16	8,925	sw.	49	w.	31	2	7	22	8.1	6.4	3.2
Oswego	335	75	91	.....	30.01	−.05	36.0	+7.0	60	13	42	16	18	30	28	.....	.....	81	3.11	−0.5	19	9,161	s.	46	w.	31	1	9	21	....	8.8	2.0
Rochester	523	86	102	29.44	30.02	−.04	37.4	+8.1	62	13	43	20	15	32	32	34	30	76	2.80	−0.1	17	7,183	sw.	44	w.	31	2	3	26	8.6	7.5	T.
Syracuse	597	97	113	29.37	30.03	−.04	36.4	+8.1	61	13	42	17	18	31	31	.....	.....	.....	2.74	+0.1	18	8,754	s.	58	s.	28	1	5	25	8.5	7.1	0.0
Erie	714	130	166	29.23	30.01	−.06	40.2	+8.3	58	31	45	24	14	35	32	37	33	77	4.72	+1.7	17	11,743	s.	55	sw.	31	1	6	24	8.3	1.3	0.0
Cleveland	762	190	201	29.19	30.03	−.06	40.4	+9.2	59	19	46	22	15	35	30	37	33	78	4.50	+1.9	16	11,363	s.	54	w.	28	4	5	22	8.1	T.	0.0
Sandusky	629	62	70	29.34	30.03	−.06	39.6	+8.4	57	20	46	24	15	34	29	.....	.....	.....	4.08	+1.7	16	6,734	sw.	37	nw.	6	4	6	21	7.7	0.3	0.0
Toledo	628	208	243	29.34	30.04	−.03	38.9	+8.5	56	12	45	23	14	33	32	35	32	82	5.74	+3.4	15	12,103	sw.	57	w.	28	5	8	18	7.0	1.5	0.0
Fort Wayne	856	113	124	29.10	30.05	.....	39.1	+11.8	56	13	46	18	31	33	31	36	34	87	3.99	.....	15	7,919	sw.	34	w.	28	5	3	23	7.5	1.5	T.
Detroit	730	218	258	29.22	30.03	−.04	37.6	+8.3	55	13	44	20	14	32	34	35	34	88	3.46	+1.1	14	9,418	sw.	44	sw.	31	4	8	19	7.5	5.5	T.
Upper Lake Region.							33.2	+8.8										82	1.92	−0.2									7.2		
Alpena	609	13	92	29.30	29.98	−.04	33.6	+8.8	55	19	39	14	31	28	25	31	28	81	2.33	+0.1	14	9,191	sw.	44	nw.	28	5	3	23	7.7	10.1	7.7
Escanaba	612	54	60	29.31	30.00	−.03	30.6	+9.0	46	20	37	0	31	24	30	28	25	81	1.45	−0.2	11	7,590	sw.	36	ne.	31	9	5	17	6.4	5.7	4.0
Grand Haven	632	54	89	29.32	30.02	−.03	36.8	+7.5	49	7	42	16	31	32	19	34	31	81	1.88	−0.6	11	10,587	w.	52	w.	28	4	7	20	7.7	6.1	4.9
Grand Rapids	707	70	87	29.25	30.03	−.02	36.6	+7.8	52	7	42	18	31	31	22	33	30	80	2.18	−0.4	13	4,942	w.	30	w.	28	4	3	24	8.1	9.0	5.5
Houghton	668	62	99	29.21	29.96	−.06	29.5	+8.6	58	19	35	1	31	24	32	.....	.....	.....	1.83	−0.6	13	7,564	w.	45	w.	13	4	8	19	7.7	13.6	10.8
Lansing	878	11	62	29.05	30.02	.....	35.0	+8.2	54	20	42	15	24	28	27	32	30	86	2.96	+0.9	14	5,174	sw.	25	nw.	28	4	7	20	7.5	8.2	3.1
Ludington	657	60	66	29.30	30.01	.....	35.8	.....	48	18	40	13	31	32	19	33	30	80	1.81	.....	11	9,903	w.	41	sw.	15	5	6	20	7.4	6.0	5.2
Marquette	734	77	111	29.17	29.99	−.05	31.4	+8.5	60	19	37	1	31	25	27	28	24	77	1.52	−1.0	14	7,776	w.	32	sw.	12	2	6	23	8.0	13.3	12.0
Port Huron	638	70	120	29.30	30.01	−.05	36.2	+8.6	53	13	42	17	14	31	32	34	31	83	3.01	+0.8	12	9,290	sw.	47	w.	28	4	8	19	7.3	6.4	0.8
Saginaw	641	69	77	29.30	30.02	.....	35.3	.....	55	20	41	16	31	29	26	33	31	89	1.22	−0.7	10	7,393	sw.	32	w.	28	4	3	24	7.7	2.7	2.1
Sault Sainte Marie	614	11	52	29.26	29.97	−.03	30.0	+9.5	46	8	35	1	31	25	23	28	26	84	2.23	−0.1	19	6,728	sw.	44	nw.	13	3	5	23	8.2	16.9	7.0
Chicago	823	140	310	29.14	30.05	−.03	39.7	+9.7	53	18	45	8	31	34	30	37	33	77	1.96	−0.1	13	9,494	w.	38	w.	27	9	7	15	6.2	4.6	1.5
Green Bay	617	109	144	29.31	29.99	−.05	32.0	+10.7	49	8	38	−2	31	26	22	29	26	80	1.19	−0.6	9	9,758	s.	46	ne.	30	7	10	14	6.7	7.7	7.3
Milwaukee	681	125	139	29.26	30.02	−.04	35.6	+9.5	52	18	42	0	31	30	34	33	30	80	2.34	+0.4	10	8,463	w.	35	n.	31	8	7	16	6.6	6.2	4.8
Duluth	1,133	11	47	28.73	30.00	−.05	24.0	+8.1	51	19	31	−19	31	17	29	22	19	84	0.82	−0.4	8	10,887	w.	55	nw.	27	11	11	9	4.8	7.5	5.0
North Dakota.							23.2	+11.2										74	0.29	−0.3									5.2		
Moorhead	940	50	58	28.97	30.03	−.05	22.6	+11.1	50	18	32	−21	31	13	29	19	14	73	0.52	−0.2	7	6,662	w.	36	nw.	12	13	8	10	4.7	4.6	3.2
Bismarck	1,674	8	57	28.23	30.08	.00	25.4	+10.7	56	11	37	−17	31	14	36	20	14	69	0.22	−0.4	2	5,827	nw.	46	nw.	12	13	11	7	4.8	3.7	2.1
Devils Lake	1,478	11	44	28.36	30.00	−.06	20.4	+12.4	51	18	30	−27	30	11	28	17	14	79	0.23	−0.2	6	7,330	w.	44	nw.	12	13	8	10	5.0	4.1	2.0
Ellendale	1,457	10	56	28.43	30.04	.....	23.6	.....	54	17	36	−20	31	12	36	.....	.....	.....	0.24	.....	2	10,100	nw.	56	nw.	12	9	11	11	5.5	2.8	2.8
Grand Forks	835	12	89	.....	.....	.....	19.9	.....	49	11	30	−25	31	9	38	.....	.....	.....	0.96	.....	8	.....	sw.	42	w.	12	10	4	17	....	9.5	4.5
Williston	1,878	41	48	27.96	30.01	−.05	24.2	+10.4	52	17	34	−24	31	14	30	19	15	74	0.18	−0.5	7	5,828	sw.	43	w.	12	8	10	13	5.9	2.1	1.2
Upper Mississippi Valley.							37.1	+9.9										79	1.92	+0.1									6.2		
Minneapolis	918	102	208	29.00	30.01	.....	29.9	.....	55	18	38	−12	31	22	27	.....	.....	.....	0.41	−0.5	6	8,130	w.	41	nw.	12	9	8	14	6.0	2.7	2.7
St. Paul	837	235	251	29.09	30.03	−.05	29.4	+10.4	54	18	38	−11	31	21	28	.....	.....	.....	0.66	−0.4	5	8,878	sw.	48	nw.	12	10	9	12	5.8	4.5	3.0
La Crosse	714	11	48	29.24	30.03	−.05	32.2	+9.9	54	18	41	−9	31	24	30	.....	.....	.....	1.53	+0.2	10	4,097	se.	21	s.	14	13	5	13	5.5	13.0	11.5
Madison	974	70	78	28.97	30.05	−.03	32.5	+9.7	53	18	39	−5	31	26	24	30	27	80	2.12	+0.4	10	8,127	sw.	39	ne.	30	7	9	15	6.6	11.6	8.1
Wausau	1,247	4	.....	28.65	30.03	.....	28.1	.....	48	19	35	−10	31	22	24	.....	.....	.....	1.65	.....	11	.....	se.	.....	.....	.....	15	1	15	5.5	10.7	9.0
Charles City	1,015	10	49	28.94	30.06	−.04	31.4	+12.4	59	18	41	−13	31	22	30	27	23	79	1.19	−0.1	6	5,141	w.	28	sw.	14	12	6	13	5.4	9.4	9.0
Davenport	606	71	79	29.38	30.05	−.05	36.8	+9.7	55	18	44	−5	31	30	30	34	31	82	1.52	−0.2	10	5,471	sw.	24	w.	27	9	7	15	6.1	0.9	0.9
Des Moines	861	84	97	29.12	30.06	−.05	35.8	+9.7	59	17	44	−5	31	27	29	32	27	74	0.61	−0.7	4	5,510	sw.	33	sw.	14	10	8	13	5.6	6.2	6.0
Dubuque	698	81	96	29.30	30.07	−.03	34.4	+9.7	54	18	41	−7	31	28	27	31	27	77	0.92	−0.8	9	4,919	s.	23	nw.	13	9	7	15	6.6	7.3	6.8
Keokuk	614	64	78	29.38	30.07	−.05	39.2	+9.6	60	7	47	0	31	31	30	35	30	74	1.79	−0.1	8	5,711	sw.	31	nw.	31	7	8	16	6.6	1.1	1.1
Cairo	358	87	93	29.69	30.09	−.06	47.8	+10.0	69	8	55	16	31	40	39	44	40	78	4.92	+1.6	15	7,230	s.	34	nw.	13	6	3	22	7.7	0.4	0.0
Peoria	609	11	45	29.39	30.07	−.04	38.0	+9.9	57	18	46	−2	31	30	38	35	33	87	2.21	−0.2	13	5,139	s.	23	nw.	27	9	7	15	5.8	0.6	0.2
Springfield, Ill.	636	10	91	29.36	30.05	−.07	40.6	+8.9	60	27	47	3	31	34	36	37	35	84	3.40	+1.0	9	6,464	s.	29	w.	31	11	3	17	6.1	0.8	0.1
Hannibal	534	74	109	29.48	30.07	−.05	40.2	+8.7	61	7	48	2	31	32	29	.....	.....	.....	2.31	+0.7	9	6,298	sw.	29	sw.	31	7	6	18	6.9	0.6	0.3
St. Louis	568	265	303	29.45	30.07	−.06	44.4	+9.6	70	27	52	11	31	37	31	40	35	75	3.30	+1.1	10	9,822	s.	49	w.	31	9	4	18	6.8	0.7	T.
Missouri Valley.							35.0	+7.6										71	0.98	−0.1									5.5		
Columbia, Mo.	784	11	84	29.22	30.07	−.05	40.2	+7.3	68	7	49	3	31	32	32	.....	.....	.....	2.53	+0.5	9	6,070	s.	31	w.	31	8	4	19	6.7	0.3	0.3
Kansas City	963	161	181	29.03	30.09	−.03	39.0	+7.5	60	17	46	0	31	32	30	35	29	71	1.12	−0.2	8	8,399	sw.	35	nw.	31	11	6	14	6.1	0.6	0.6
St. Joseph	967	11	49	29.01	30.07	.....	37.2	.....	60	16	46	−2	31	29	30	32	27	73	0.35	.....	6	5,951	nw.	31	nw.	31	12	6	13	5.6	1.2	1.1
Springfield, Mo.	1,324	98	104	28.65	30.08	−.05	42.8	+7.3	69	27	51	7	31	34	36	39	36	81	2.92	+0.2	9	7,988	nw.	34	sw.	27	11	8	12	5.4	T.	0.0
Iola	984	11	50	29.01	30.09	−.03	38.6	+6.1	61	7	47	5	31	30	34	.....	.....	.....	1.14	+0.2	7	5,098	s.	26	n.	12	8	7	16	6.8	T.	T.
Topeka	987	92	107	.....	.....	.....	37.7	+6.6	61	17	46	−1	31	29	33	.....	.....	.....	0.55	−0.3	7	7,107	n.	40	n.	12	10	7	14	5.8	0.8	0.8
Drexel	1,299	10	54	28.63	30.05	.....	32.6	.....	57	7	42	−10	31	23	31	.....	.....	.....	0.55	.....	7	8,144	sw.	39	sw.	14	8	12	11	5.6	6.5	4.0
Lincoln	1,189	11	84	28.79	30.10	−.02	35.0	+8.1	62	7	44	−5	31	26	36	30	25	75	0.52	−0.2	6	6,735	s.	30	s.	14	8	7	16	6.5	2.5	2.0
Omaha	1,105	115	122	28.87	30.09	−.02	35.2	+8.8	61	17	44	−6	31	27	29	30	25	71	0.58	−0.3	5	5,850	nw.	33	n.	29	8	11	12	5.5	5.9	4.8
Valentine	2,598	47	54	27.28	30.09	−.01	29.0	+4.4	66	18	42	−26	31	16	45	24	17	67	0.41	−0.2	3	6,818	w.	33	sw.	11	12	11	8	4.7	7.5	5.3
Sioux City	1,135	94	164	28.84	30.09	−.03	32.4	+9.3	59	18	41	−10	31	24	30	27	21	66	0.73	0.0	4	8,176	nw.	40	nw.	12	11	11	9	4.7	8.9	7.5
Huron	1,306	59	74	28.64	30.08	−.06	28.6	+8.9	58	18	40	−16	31	17	41	23	17	69	0.22	−0.4	5	6,760	nw.	36	nw.	12	12	16	3	4.1	1.6	1.6
Pierre	1,572	70	75	28.36	30.08	−.02	29.7	+7.9	59	15	42	−15	31	18	44	23	17	68	0.24	−0.3	2	5,449	nw.	44	nw.	12	17	4	10	4.2	5.0	4.0
Yankton	1,233	49	57	28.71	30.07	−.04	32.0	+9.1	64	18	41	−12	31	23	39	.....	.....	.....	0.77	0.0	4	5,651	w.	30	nw.	12	9	12	10	5.6	8.5	8.5

TABLE I.—*Climatological data for Weather Bureau Stations, December, 1923.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sheet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
Northern Slope.							**25.1**	**+1.3**										**69**	**0.63**	**−0.2**										**5.2**		
Billings	3,140	5	....	.....	.....	.....	27.6	.....	60	18	41	−38	31	14	43	...	...	...	0.33	.....	2	.....	nw.	....	.....	.....	18	6	7	....	7.5	5.5
Havre	2,505	11	44	27.30	30.02	−.03	25.6	+5.2	60	6	37	−35	30	14	42	22	17	73	0.69	+0.1	5	7,978	sw.	48	sw.	6	9	8	14	6.0	6.7	3.0
Helena	4,110	87	112	25.79	30.13	.00	24.8	+0.6	50	6	33	−30	31	17	29	21	14	65	0.56	−0.2	7	6,183	sw.	40	sw.	6	6	9	16	6.7	5.7	4.5
Kalispell	2,973	48	56	26.94	30.11	+.04	24.5	+0.6	49	4	31	−26	31	18	28	22	19	80	1.55	−0.3	9	3,801	nw.	30	sw.	5	4	11	16	....	13.9	11.3
Miles City	2,371	48	55	27.49	30.13	+.03	28.6	+7.6	57	15	40	−27	31	17	33	22	15	64	0.29	−0.3	4	4,602	s.	36	w.	7	16	5	10	4.2	4.3	4.2
Rapid City	3,259	50	58	26.60	30.12	+.03	30.8	+2.3	60	11	42	−22	31	19	45	24	16	59	0.22	−0.2	3	6,116	w.	40	sw.	7	14	4	13	4.9	2.6	2.2
Cheyenne	6,088	84	101	23.94	30.10	+.01	27.4	−1.1	61	16	40	−28	31	15	49	21	14	63	0.28	0.0	7	11,391	w.	81	w.	28	12	13	6	4.4	4.1	2.0
Lander	5,372	60	68	24.63	30.22	+.06	17.0	−2.2	52	6	28	−30	31	6	47	14	8	70	0.48	−0.2	5	2,812	sw.	64	sw.	6	11	15	5	4.5	6.0	5.0
Sheridan	3,790	10	47	26.16	30.15	.....	23.6	.....	62	6	36	−32	31	11	43	18	14	73	0.82	.....	6	3,475	s.	40	sw.	6	14	7	10	4.8	7.7	5.8
Yellowstone Park	6,200	11	48	23.86	30.24	+.08	17.0	−4.6	44	16	27	−34	31	7	52	14	10	76	1.22	−0.6	17	6,191	s.	40	s.	6	4	14	13	6.5	12.8	11.0
North Platte	2,821	11	51	27.12	30.16	+.06	30.4	+3.7	62	7	42	−17	31	18	46	23	18	71	0.39	−0.1	4	4,770	n.	31	n.	12	12	6	13	5.2	4.3	3.8
Middle Slope.							**35.6**	**+2.4**										**73**	**0.78**	**0.0**										**5.3**		
Denver	5,292	106	113	24.70	30.11	+.03	30.5	−1.8	66	7	42	−13	31	19	40	26	19	66	0.95	+0.4	6	5,656	s.	35	w.	7	13	12	6	4.4	15.3	0.4
Pueblo	4,685	80	86	25.28	30.09	+.01	32.2	+0.5	70	7	44	−14	31	20	45	27	21	69	0.35	−0.1	4	3,903	nw.	35	nw.	29	9	13	9	5.1	3.5	1.9
Concordia	1,392	50	58	28.58	30.10	−.01	35.6	+6.1	61	7	44	−3	31	27	34	30	25	72	0.17	−0.3	4	5,367	s.	27	n.	9	10	9	12	5.8	0.5	0.4
Dodge City	2,509	11	51	27.47	30.15	+.05	34.5	+1.9	73	7	45	−4	31	24	42	28	25	79	0.48	−0.1	5	6,983	nw.	30	sw.	14	14	4	13	4.8	2.2	0.8
Wichita	1,358	139	158	28.61	30.08	−.03	38.6	+4.4	59	7	47	1	31	30	38	34	29	74	0.67	−0.1	4	9,208	s.	42	sw.	7	12	11	8	5.3	0.1	T.
Broken Arrow	765	11	52	29.25	30.09	.....	43.0	.....	71	27	51	9	31	35	39	...	...	...	3.72	.....	...	9,803	n.	42	ne.	10	9	7	15	6.1	T.	0.0
Muskogee	652	4	....	.....	.....	.....	45.2	.....	72	27	54	12	31	36	35	...	...	...	5.87	.....	14	.....	nw.	....	.....	.....	10	10	11	....	0.0	0.0
Oklahoma City	1,214	10	47	28.79	30.11	.00	42.2	+3.6	70	27	51	7	31	34	44	37	33	77	2.06	+0.3	6	8,316	s.	35	s.	7	10	11	10	5.5	0.0	0.0
Southern Slope.							**41.4**	**−2.4**										**78**	**1.46**	**+0.6**										**6.2**		
Abilene	1,738	10	52	28.27	30.11	.00	46.4	+1.4	76	29	55	16	31	38	47	41	37	78	1.92	+0.8	7	7,025	sw.	31	sw.	30	9	2	20	6.7	0.0	0.0
Amarillo	3,676	10	49	25.30	30.13	+.04	33.9	−2.5	69	7	42	1	31	26	39	30	27	80	1.11	+0.3	9	7,902	sw.	40	nw.	12	11	8	12	5.6	10.8	0.8
Del Rio	944	64	71	29.08	30.08	−.02	52.2	−0.2	79	29	59	28	14	45	26	...	...	...	0.94	0.0	12	5,420	nw.	31	nw.	13	8	7	16	6.7	0.0	0.0
Roswell	3,569	75	85	26.41	30.13	+.06	33.0	−8.2	76	7	43	−4	14	23	48	29	24	76	1.89	+1.4	9	4,853	n.	33	ne.	10	11	4	16	5.8	13.4	0.0
Southern Plateau.							**41.0**	**−1.1**										**64**	**1.09**	**+0.4**										**4.4**		
El Paso	3,762	110	133	26.23	30.07	+.04	42.6	−2.2	67	8	50	16	13	35	30	37	32	70	0.93	+0.4	10	8,279	nw.	60	ne.	10	12	4	15	5.6	2.0	0.0
Santa Fe	7,013	38	53	23.20	30.10	+.04	29.1	−1.6	53	7	38	6	31	20	25	25	20	73	0.98	+0.2	13	3,545	ne.	39	w.	30	7	11	13	6.2	12.4	0.8
Flagstaff	6,907	10	59	23.29	30.06	−.06	29.2	+0.8	59	6	38	4	22	20	40	25	....	73	3.89	.....	13	6,379	e.	54	ne.	10	12	4	15	....	19.2	7.0
Phoenix	1,108	11	81	28.88	30.03	−.01	52.0	+0.1	71	3	62	29	12	42	30	45	39	68	2.23	+1.6	11	3,737	e.	31	w.	30	14	8	9	4.6	0.0	0.0
Yuma	141	9	54	29.88	30.04	−.01	53.4	−1.8	73	16	63	35	12	44	30	46	38	59	1.28	+0.8	8	4,407	n.	42	n.	10	19	7	5	3.3	0.0	0.0
Independence	3,957	5	25	26.02	30.16	+.04	39.7	−1.9	64	3	53	11	31	27	34	29	14	39	0.01	−0.8	1	7,102	nw.	38	nw.	7	24	4	3	2.3	0.0	0.0
Middle Plateau.							**28.8**	**−2.3**										**69**	**0.64**	**−0.4**										**4.8**		
Reno	4,532	74	81	25.54	30.20	+.05	32.6	−1.1	61	4	45	8	11	20	46	27	19	61	0.29	−1.4	5	3,810	w.	40	w.	6	13	13	5	4.1	1.2	0.5
Tonopah	5,090	12	20	24.07	30.16	.....	29.4	.....	52	6	37	9	10	22	24	24	15	56	0.19	−0.6	3	6,293	w.	32	nw.	7	15	11	5	3.6	3.0	T.
Winnemucca	4,344	18	56	25.72	30.25	+.07	25.2	−4.8	52	6	37	−10	27	13	38	22	18	77	1.02	0.0	9	5,157	ne.	37	nw.	7	10	9	12	5.2	10.3	3.8
Modena	5,479	10	43	24.64	30.14	+.02	26.9	−4.8	56	6	39	2	31	15	42	22	16	67	0.41	−0.2	6	7,003	e.	45	ne.	10	15	9	7	4.4	2.3	0.3
Salt Lake City	4,360	163	203	25.71	30.20	+.05	29.3	−2.6	54	6	36	12	11	23	28	26	22	75	0.92	−0.4	6	4,181	nw.	38	ne.	7	8	4	19	6.8	13.0	2.9
Grand Junction	4,602	60	68	25.45	30.12	+.02	30.0	+1.8	52	26	40	6	31	19	32	26	22	76	0.98	+0.5	6	2,807	nw.	24	nw.	7	16	6	9	4.5	9.4	2.2
Northern Plateau.							**31.8**	**−0.2**										**77**	**1.49**	**−0.2**										**7.2**		
Baker	3,471	48	53	26.53	30.22	+.06	26.1	−1.3	51	6	34	3	31	18	25	24	21	79	1.16	−0.4	8	4,459	se.	32	s.	6	4	6	21	7.7	10.8	3.4
Boise	2,739	78	86	27.30	30.25	+.05	31.6	−0.5	54	4	39	15	30	24	32	29	23	71	0.79	−0.9	6	3,428	se.	26	se.	4	9	13	9	5.8	4.7	3.6
Lewiston	757	40	48	29.32	30.15	+.02	37.2	−0.3	58	6	44	9	31	30	21	...	...	...	1.83	+0.3	11	3,574	e.	29	nw.	28	5	7	19	7.6	2.2	1.2
Pocatello	4,477	60	68	25.55	30.23	+.04	25.6	−2.8	47	7	34	1	31	18	29	22	19	78	1.15	+0.3	7	7,134	se.	40	sw.	7	7	9	15	6.5	3.7	0.5
Spokane	1,929	101	110	28.01	30.12	+.04	32.4	+1.9	53	4	38	1	31	27	21	30	27	81	1.84	−0.8	10	5,307	sw.	32	sw.	6	3	8	20	7.7	6.5	1.4
Walla Walla	991	57	65	29.04	30.14	+.02	38.0	+2.0	67	4	44	7	31	32	24	34	31	78	2.18	+0.1	12	4,359	sw.	30	sw.	25	5	6	20	7.7	4.7	4.4
North Pacific Coast region.							**42.4**	**+0.3**										**86**	**7.64**	**0.0**										**8.3**		
North Head	211	11	56	29.83	30.03	+.03	44.4	+0.1	58	17	48	22	31	40	14	43	41	87	8.30	+0.8	29	16,199	se.	88	s.	17	1	6	24	8.5	5.2	2.0
Port Angeles	29	8	53	.....	30.01	.....	41.0	.....	58	11	47	16	31	35	24	...	...	...	5.45	+0.3	18	5,244	s.	38	sw.	6	1	8	22	....	3.1	2.0
Seattle	125	215	250	29.94	30.08	+.07	42.2	+1.0	57	17	46	20	31	38	14	40	37	83	3.31	−2.0	19	9,164	s.	66	s.	25	2	7	22	8.1	0.4	T.
Tacoma	213	113	120	29.85	30.03	+.05	41.8	+1.5	59	4	47	17	31	36	19	...	...	...	4.83	−2.5	21	7,250	s.	52	s.	25	1	6	24	8.4	T.	0.0
Tatoosh Island	86	9	57	.....	29.96	.00	44.1	+0.2	58	17	48	24	30	40	16	...	...	84	21.01	+6.4	28	17,296	e.	90	s.	17	2	4	25	....	T.	0.0
Yakima	1,071	5	....	.....	.....	.....	32.2	.....	57	4	42	8	26	22	37	...	...	...	1.07	.....	6	.....	ne.	....	.....	.....	9	6	16	....	6.5	1.0
Medford	1,425	4	....	.....	.....	.....	36.4	.....	64	17	44	20	1	29	32	34	32	88	1.53	.....	15	.....	se.	....	.....	.....	3	3	25	....	0.0	0.0
Portland, Oreg.	153	68	106	29.96	30.13	+.06	41.5	+0.3	55	6	46	17	31	37	17	40	38	88	6.25	−1.1	19	4,984	se.	30	w.	24	2	0	29	9.3	0.1	T.
Roseburg	510	9	57	29.63	30.19	+.08	40.6	−1.2	60	6	48	22	31	34	26	38	36	88	4.31	−1.6	17	1,906	s.	22	sw.	4	3	10	18	7.1	2.0	2.0
Middle Pacific Coast Region.							**47.5**	**−1.2**										**73**	**1.83**	**−2.7**										**4.4**		
Eureka	62	73	89	30.14	30.21	+.09	45.3	−2.7	68	17	52	31	27	38	25	43	41	84	4.93	−2.3	16	3,860	se.	39	sw.	4	6	8	17	6.7	T.	T.
Point Reyes	490	7	18	29.58	30.10	.....	50.4	−0.2	64	1	55	36	31	46	16	...	...	...	0.73	.....	8	14,595	nw.	73	nw.	7	18	8	5	3.4	0.0	0.0
Red Bluff	332	50	56	29.80	30.17	+.03	45.1	−1.0	67	3	54	31	31	36	30	40	32	64	0.64	−3.8	4	3,922	nw.	28	se.	6	16	9	6	4.2	0.0	0.0
Sacramento	69	106	117	30.08	30.16	+.02	45.6	−0.6	62	10	53	32	11	38	25	42	37	74	0.94	−2.6	6	5,086	se.	36	n.	1	18	6	7	4.0	0.0	0.0
San Francisco	155	208	243	29.98	30.14	+.02	51.0	−0.3	65	10	56	42	28	46	16	46	40	70	1.91	−2.3	8	5,992	n.	64	ne.	1	15	11	5	3.8	0.0	0.0
San Jose	141	12	110	30.00	30.16	.....	47.4	−2.5	74	4	59	28	27	36	43	....	.....	.....	0.71	−2.3	8	4,333	nw.	30	nw.	1	15	9	7	4.0	0.0	0.0
South Pacific Coast Region.							**53.9**	**+0.8**										**57**	**0.86**	**−1.3**										**3.2**		
Fresno	327	89	98	29.79	30.16	+.03	46.2	−0.6	65	17	56	28	10	36	30	40	33	66	0.24	−1.3	6	3,722	nw.	37	nw.	8	16	10	5	3.2	0.0	0.0
Los Angeles	338	159	191	29.69	30.06	−.01	58.8	+2.2	80	16	67	42	31	50	25	47	35	49	0.80	−2.1	6	5,062	ne.	36	n.	9	20	8	3	3.0	0.0	0.0
San Diego	87	62	70	29.94	30.01	−.04	57.4	+1.4	75	2	66	41	12	49	26	49	42	62	1.65	−0.2	8	4,841	e.	35	nw.	8	14	10	7	4.2	0.0	0.0
San Luis Obispo	201	32	40	29.90	30.12	+.01	53.2	+0.4	80	24	66	30	11	40	42	43	32	52	0.73	−1.6	6	3,434	n.	21	ne.	27	20	8	3	2.6	0.0	0.0
West Indies.																																		
San Juan, P. R.	82	9	54	29.93	30.02	.....	75.0	.....	81	6	79	66	18	71	13	...	...	...	4.17	−2.0	21	[1]1,728	e.	42	e.	9	8	15	8	5.5	0.0	0.0
Panama Canal.																																		
Balboa Heights	118	7	97	29.72	29.84	.00	80.1	+0.2	91	20	87	70	15	73	17	74	73	85	3.94	−0.2	15	4,496	nw.	25	ne.	17	0	28	3	6.0	0.0	0.0
Colon	36	7	97	29.82	29.86	.00	80.6	+0.7	87	21	85	72	15	76	12	76	74	82	5.12	−6.0	19	10,106	ne.	33	ne.	29	7	17	7	5.7	0.0	0.0
Alaska.																																		
Juneau	80	11	54	29.49	29.58	.....	32.0	.....	46	21	35	9	29	28	15	30	27	81	13.13	.....	27	6,865	se.	35	e.	21	2	2	27	9.1	43.6	4.1

TABLE II.—*Data furnished by the Canadian Meteorological Service, December, 1923.*

Stations.	Altitude above mean sea level. Jan. 1. 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.88	29.93	+.04	34.6	+6.4	39.8	29.5	55	19	4.13	−0.50	19.5
Halifax, N. S.	88	29.85	29.96	.00	33.0	+5.4	39.6	26.5	56	7	6.34	+1.22	26.1
Yarmouth, N. S.	65	29.86	29.93	−.05	35.3	+4.6	41.2	29.4	57	10	6.86	+1.82	7.4
Charlottetown, P. E. I.	38	29.89	29.93	−.01	32.0	+7.7	37.3	26.8	53	10	2.82	−0.84	24.5
Chatham, N. B.	28	29.85	29.88	−.06	26.5	+9.5	34.2	18.8	53	−5	3.07	−0.15	11.1
Father Point, Que.	20												
Quebec, Que.	296	29.65	29.99	−.02	26.8	+11.6	31.9	21.8	49	0	3.98	+0.29	20.8
Montreal, Que.	187	29.77	29.99	−.04	29.8	+11.5	35.2	24.3	51	3	4.54	+0.89	23.6
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.72	30.00	−.02	29.7	+12.7	35.5	23.9	52	−4	3.42	+0.51	16.8
Kingston, Ont.	285	29.68	30.00	−.04	34.8	+11.1	39.9	29.6	53	9	2.48	−0.76	1.5
Toronto, Ont.	379	29.58	30.00	−.05	36.1	+9.1	41.3	31.0	53	18	3.02	+0.11	5.5
Cochrane, Ont.	930												
White River, Ont.	1,244	28.56	29.92	−.05	17.2	+7.5	27.3	7.1	43	−25	0.72	−0.99	6.9
Port Stanley, Ont.	592	29.38	30.04	−.03	35.5	+7.1	40.0	31.0	48	12	4.46	+2.04	7.4
Southampton, Ont.	656				35.3	+8.6	39.9	30.8	50	19	2.56	−1.42	4.2
Parry Sound, Ont.	688	29.25	29.96	−.05	30.4	+9.2	36.2	24.6	46	5	4.00	−0.48	8.6
Port Arthur, Ont.	644	29.24	29.97	−.02	22.5	+9.3	28.6	16.5	45	−14	1.13	+0.26	7.5
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.06	29.96	−.06	14.6	+8.9	23.8	5.5	40	−26	0.25	−0.37	2.5
Le Pas, Man.	860				8.8		20.2	−2.5	43	−27	0.80		8.0
Qu'Appelle, Sask.	2,115	27.59	29.92	−.08	17.7	+10.3	26.8	8.6	44	−27	0.57	+0.05	5.0
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759				19.5		28.3	10.8	48	−24	0.31		3.1
Swift Current, Sask.	2,392	27.28	30.00	+.01	21.2	+5.2	31.0	11.4	48	−30	0.18	−0.60	1.8
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150	27.48	29.83	−.10	20.1	+7.0	29.4	10.9	52	−25	0.46	−0.24	4.6
Prince Albert, Sask.	1,450	28.28	29.93	−.08	14.2	+11.4	24.7	3.8	47	−29	0.31	−0.43	3.1
Battleford, Sask.	1,592	28.07	29.87	−.12	18.3	+12.9	28.9	7.7	50	−28	0.22	−0.10	2.2
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.75	30.01	+.04	41.5	+0.3	45.0	38.0	55	17	4.25	−3.73	T.
Barkerville, B. C.	4,180												

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Medicine Hat, Alb.	2,144	27.62	29.91	−.09	38.0	+10.6	49.7	26.3	63	12	0.42	−0.50	4.0
Calgary, Alb.	3,428	26.39	30.00	+.02	38.1	+12.3	53.4	23.0	70	2	0.44	−0.44	4.4
Banff, Alb.	4,521	25.38	30.05	+.09	30.9	+5.1	39.2	22.7	49	7	0.66	−1.61	6.6
Kamloops, B. C.	1,262	28.85	30.18	+.22	37.7	+4.3	42.2	33.2	58	24	0.51	−0.95	1.7
Barkerville, B. C.	4,180	25.62	29.98	+.08	31.1	+7.5	37.9	24.3	48	10	3.36	+0.07	29.7
Edmonton, Alb.	2,150	27.57	29.89	−.08	34.3	+11.4	46.3	22.4	65	3	0.17	−0.41	1.5

SEISMOLOGICAL REPORTS FOR DECEMBER, 1923.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, February 3, 1924.]

TABLE 1.—*Noninstrumental earthquake reports, December, 1923.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1923.	*H. m.*	CALIFORNIA.	° ′	° ′			*Sec.*			
Dec. 4	20 50	Camptonville	39 30	121 00	4	1	60	Faint		E. Hall.
11	16 40	Calexico	32 41	115 30	3	3	3	None	Also at 16:41 and 17:04	F. C. Cihak.
15	2 20	do	32 41	115 30	3	1	3 *ca.*	Faint	Felt by several.	M. J. Dowd.
19	7 35	Santa Maria	34 45	120 30	2?	1	20	None		A. A. Howard.
31	13 00	Valley Center	33 15	117 00	3	1	2	Rumbling	Felt by several.	B. Amago.
		WYOMING.								
12	17 55	South Pass City	42 30	108 50	5	1	20 *ca.*	do	Felt by many	J. Sherlock.

TABLE 2.—*Instrumental seismological reports, December, 1923.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International. [For significance of symbols and description of stations, see REVIEW for January, 1923.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. AE	Amplitude. AN	Distance.	Remarks.
ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*								
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 18	.....	P_N	13 31 16	.....	.....	.....	.....	
		S?	13 31 52	1	.....	*200	.....	
		L_E?	13 32 12	4	.....	.....	.....	
		Me	13 32 26	4	*200	.....	.....	
		F_E	13 33 33	.....	.....	.....	.....	
		F_N	13 32 40	.....	.....	.....	.....	
19	.....	P_N	16 07 31	1	.....	.....	.....	
		S?	16 08 03	2	.....	*100	.....	
		L_E?	16 08 18	7	.....	.....	.....	
		M_E	16 08 25	7	*100	.....	.....	
		F_E	16 09 49	.....	.....	.....	.....	
		F_N	16 10 15	.....	.....	.....	.....	
26	.....	eL_E	8 03 05	12	.....	.....	.....	Nothing on N.
		M_E	8 04 50	8	*100	.....	.....	
		F_E	8 14 ..	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. AE	Amplitude. AN	Distance.	Remarks.
CALIFORNIA. *Theosophical University, Point Loma.*								
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 26	.....	.....	15 00 00	.....	50	50	.....	Tremors during preceding 24 hours.
27	.....	.....	.....	.....	50	50	.....	
29	.....	.....	.....	.....	50	50	.....	
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5	.....	eL_E	23 10 ..	.....	.....	.....	.....	
		F_E	23 25 ..	.....	.....	.....	.....	
7	.....	e_N	16 13 ..	.....	.....	.....	.....	
		M_N	16 15 20	28	.....	15	.....	
		F	16 20 ..	.....	.....	.....	.....	
7	.....	e_E	19 39 00	.....	.....	.....	.....	
		M_E	19 40 20	20	10	.....	.....	
		F_E	19 47 ..	.....	.....	.....	.....	
ILLINOIS. *U. S. Weather Bureau, Chicago.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 2	.....	eL	15 32 ..	.....	.....	.....	.....	
		L	15 36 ..	16	.....	.....	.....	
		F	16 *ca.*	.....	.....	.....	.....	
3	.....	eL	8 57 30	18	.....	.....	.....	
		F	9 02 *ca.*	.....	.....	.....	.....	
5	.....	P	21 08 05	.....	.....	.....	8,300	
		S?	21 17 42	.....	.....	.....	.....	
		eL	21 32 40	.....	.....	.....	.....	
		L	21 34 40	22	.....	.....	.....	
		L	21 41 ..	20	.....	.....	.....	
		L	21 45 ..	18	.....	.....	.....	
6	.....	F?	0 20 *ca.*	.....	.....	.....	.....	Micros.
11	.....	eL	6 09 23	.....	.....	.....	.....	
		L	6 11 ..	22	.....	.....	.....	
		L	6 16 ..	18	.....	.....	.....	
		F	6 50 *ca.*	.....	.....	.....	.....	
13	.....	eL	17 01 00	24	.....	.....	.....	
		F	17 20 ..	.....	.....	.....	.....	Lost in heavy micros.
14	.....	iP	10 45 26	.....	.....	.....	1,800	
		S	10 48 33	.....	.....	.....	.....	
		L	10 49 32	.....	.....	.....	.....	
		L	10 55 ..	18	.....	.....	.....	
		L	11 00 ..	15	.....	.....	.....	
		F	11 50 *ca.*	.....	.....	.....	.....	
16	.....	P	7 44 02	.....	.....	.....	3,900?	
		S	7 49 35	.....	.....	.....	.....	
		eL	7 54 00	.....	.....	.....	.....	
		F	9 *ca.*	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period T.	Amplitude. AE	Amplitude. AN	Distance.	Remarks.
ILLINOIS. *U. S. Weather Bureau, Chicago*—Continued.								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 21	.....	P	9 57 04	.....	.....	.....	6,250	
		S	10 05 09	.....	.....	.....	.....	
		L	10 15 10	.....	.....	.....	.....	
		L	10 15 18	22	.....	.....	.....	
		L	10 21 ..	17	.....	.....	.....	
		L	10 25 ..	15	.....	.....	.....	
		F	11 30 *ca.*	.....	.....	.....	.....	
26	.....	e?	8 07 24	.....	.....	.....	.....	
		F	8 35 ..	.....	.....	.....	.....	
27	.....	e?	15 03 ..	.....	.....	.....	.....	
		eL	15 28 ..	18	.....	.....	.....	
		F	16 *ca.*	.....	.....	.....	.....	
28	.....	eL	23 15 ..	.....	.....	.....	.....	
		L	23 22 ..	18	.....	.....	.....	
		F	23 50 *ca.*	.....	.....	.....	.....	
NEW YORK. *Cornell University, Ithaca.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5	.....	P	21 07 43	.....	.....	.....	.....	Micros.
		eS	21 17 18	.....	.....	.....	.....	
		eL	21 30 ..	.....	.....	.....	.....	
		L	21 32 ..	23	.....	.....	.....	
		F	22 00 ..	.....	.....	.....	.....	
CANAL ZONE. *Panama Canal, Balboa Heights.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Miles.*	
Dec. 14	.....	P_E	12 33 29	.....	.....	.....	800 *ca.*	To the south.
		P_N	12 33 24	.....	.....	.....	.....	
		S_E	12 35 49	.....	.....	.....	.....	
		S_N	12 35 44	.....	.....	.....	.....	
		L_E	12 36 25	.....	.....	.....	.....	
		L_N	12 36 04	.....	.....	.....	.....	
		M_E	12 36 25	.....	*300	.....	.....	
		M_N	12 36 28	.....	.....	*500	.....	
		F_E	12 50 00	.....	.....	.....	.....	
		F_N	12 54 00	.....	.....	.....	.....	
20	.....	P_E	23 58 12	.....	.....	.....	70 *ca.*	
		P_N	23 58 08	.....	.....	.....	.....	
		L_E	23 58 32	.....	.....	.....	.....	
		L_N	23 58 30	.....	.....	.....	.....	
		M_E	23 58 34	.....	*1200	.....	.....	
		M_N	23 58 35	.....	.....	*800	.....	
		F_E	23 59 52	.....	.....	.....	.....	
21	.....	F_N	0 00 08	.....	.....	.....	.....	
21	.....	P_E	0 02 44	.....	.....	.....	.....	
		P_N	0 02 48	.....	.....	.....	.....	
		F_E	0 03 20	.....	.....	.....	.....	
		F_N	0 04 04	.....	.....	.....	.....	
22	.....	P_E	9 58 06	.....	.....	.....	700 *ca.*	Direction southerly.
		P_N	9 58 04	.....	.....	.....	.....	
		S_E	9 59 14	.....	.....	.....	.....	
		S_N	9 59 26	.....	.....	.....	.....	
		L_E	9 59 54	.....	.....	.....	.....	
		L_N	10 00 04	.....	.....	.....	.....	
		M_E	10 00 06	.....	*1100	.....	.....	
		M_N	10 00 46	.....	.....	*6000	.....	
		F_E	10 19 00	.....	.....	.....	.....	
		F_N	10 21 00	.....	.....	.....	.....	
23	.....	P_E	18 19 00	.....	.....	.....	.....	
		P_N	18 19 10	.....	.....	.....	.....	
		F	18 24 00	.....	.....	.....	.....	
24	.....	P	20 01 00	.....	.....	.....	.....	
		F	20 04 00	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. AE	Amplitude. AN	Distance.	Remarks.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 22	.....	eL_E	10 03 54	24	.....	.....	.....	Wind tremors obscure preliminaries.
		eL_N	10 05 42	20	.....	.....	.....	
		M_E	10 05 46	24	*300	.....	.....	
		M_N	10 06 22	18	.....	*100	.....	
		F_E	10 24 ..	.....	.....	.....	.....	
		F_N	10 16 ..	.....	.....	.....	.....	

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, December, 1923*—Continued.

CANADA. *Dominion Observatory, Ottawa.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 2	.....	e.....	15 13 48	.....	.....	.....	.....	On M. S. No. 17 only.
		L.....	15 40 ..	19	5	.....	.....	Sinusoidal L waves.
		L.....	16 00 ..	16	.....	.....	.....	
		F.....	17 00 *ca*	.....	.....	.....	.....	
3	.....	eL.....	8 56 ..	.....	.....	.....	.....	On M. S. No. 17 only.
		L.....	8 59 ..	19	1.5	.....	.....	Sinusoidal L waves.
		F.....	9 15 ..	.....	.....	.....	.....	
5	.....	*O*.....	20 56 56	.....	.....	.....	7,640	
		iP17...	21 07 58	.....	.....	.....	.....	VL averages 245 km/m.
		iS17...	21 17 00	.....	.....	.....	.....	
		eL.....	21 28 00	23	4.5	.....	.....	
		M.....	21 39 ..	15	7	.....	.....	
		L.....	21 43 ..	13	1	.....	.....	
		LR17..	23 16 ..	.....	.....	.....	.....	Irregular.
		F.....	.....	.....	.....	.....	.....	Lost in next quake, which may, however, be LR2 of this quake.
5	.....	(eL)...	23 18 ..	.....	.....	.....	.....	Irregular.
		L.....	23 39 ..	37	8	.....	.....	Sinusoidal L waves.
		L.....	23 57 ..	25	3.5	.....	.....	Some micros.
6	.....	L.....	0 09 ..	16	1	.....	.....	
		F.....	0 50 *ca*	.....	.....	.....	.....	
7	.....	eL.....	(16 30)	.....	.....	.....	.....	No. 17 only.
		L.....	16 32 ..	.....	.....	.....	.....	Irregular.
		F.....	*to* 40 ..	.....	.....	.....	.....	
11	.....	eL.....	6 11 ..	28	.....	.....	.....	No. 17.
		L.....	6 16 ..	23	1.5	.....	.....	
		L.....	6 24 ..	16	1	.....	.....	
		L.....	6 33 ..	14	.....	.....	.....	
		F.....	6 50 ..	.....	.....	.....	.....	
13	.....	e.....	17 05 06	.....	.....	.....	.....	No. 17. Micros mask record.
		e.....	17 07 36	.....	.....	.....	.....	
		eL.....	17 11 ..	.....	.....	.....	.....	
		L.....	17 12 ..	.....	.....	.....	.....	Irregular.
		F.....	17 25 ..	.....	.....	.....	.....	
14	.....	*O*.....	(10 42 23)	.....	.....	.....	(1,820)	Time uncertain.
		iP17...	10 46 15	.....	.....	.....	.....	
		iS17...	(10 49 22)	.....	.....	.....	.....	
		eL.....	(10 50)	.....	.....	.....	.....	
		M.....	10 58 30	23	9	.....	.....	
		L17...	11 08 ..	10	.....	.....	.....	
		F.....	11 45 *ca*	.....	.....	.....	.....	
15	.....	eL.....	12 52 *to*	.....	.....	.....	.....	Irregular: L lost in micros.
		F.....	13 05 ..	.....	.....	.....	.....	
16	.....	*O*.....	7 36 48	.....	.....	.....	.....	
		eP17..	7 45 03	.....	.....	.....	.....	
		eS17...	7 51 34	.....	.....	.....	.....	
		eSR117	(7 54)36	.....	.....	.....	.....	
		eL.....	(7 58)	.....	.....	.....	.....	Irregular; amplitude less than a micron.
		F.....	8 20 ..	.....	.....	.....	.....	
19	.....	eL.....	20 14 30	(20)	.....	.....	.....	Sinusoidal L waves lost in heavy micros.
		F.....	20 20 ..	.....	.....	.....	.....	
21	.....	*O*.....	(9 59 38)	.....	.....	.....	(2,940)	
		eP.....	(10 05 27)	.....	.....	.....	.....	
		eS.....	10 10 06	.....	.....	.....	.....	
		eL.....	10 13 00	40	23	.....	.....	
		L.....	10 21 ..	18	14	.....	.....	
		L.....	10 25 ..	14	6	.....	.....	
		F.....	11 10 *ca*.	.....	.....	.....	.....	
22	.....	eL.....	18 15 ..	.....	.....	.....	.....	Faint trace of sinusoidal L waves in micros.
		F.....	18 24 ..	.....	.....	.....	.....	
26	.....	i.....	8 09 52	.....	.....	.....	.....	
		e.....	8 10 50	.....	.....	.....	.....	
		e.....	8 12 22	.....	.....	.....	.....	
		eL.....	8 16 32	.....	.....	.....	.....	
		L.....	8 19 18	.....	.....	.....	.....	
		F.....	8 30 ..	.....	.....	.....	.....	
27	.....	e.....	15 03 ..	.....	.....	.....	.....	Preliminaries masked by micros.
		e.....	15 09 24	.....	.....	.....	.....	
		eL.....	15 28 ..	26	4	.....	.....	
		L.....	15 38 ..	20	3	.....	.....	
		F.....	15 45 ..	.....	.....	.....	.....	

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 28	.....	eL.....	18 07 ..	.....	.....	.....	.....	Masked by micros.
		L.....	18 15 ..	22	4	.....	.....	
		L.....	18 26 ..	13	1	.....	.....	
		F.....	18 45 *ca*.	.....	.....	.....	.....	

CANADA. *Meteorological Service of Canada, Victoria.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 2	.....	P_E.....	15 24 28	12	.....	.....	.....	N-S too small to measure.
		L_E.....	15 29 18	15	.....	.....	.....	
		M_E.....	15 30 18	15	7	.....	.....	
		F_E.....	15 51 33	.....	.....	.....	.....	
5	.....	M_E.....	21 47 59	.....	26	.....	.....	Heavy micros mask P, S, L.
11	.....	L_E.....	5 54 04	15	.....	.....	.....	Large micros.
		M_E.....	5 57 17	18	14	.....	.....	
13	.....	M_E.....	17 14 32	10	7	.....	.....	Micros.
		M_N.....	17 12 42	6	.....	6	.....	
14	.....	L_E.....	11 05 02	20	.....	.....	.....	N-S masked by micros.
		M_E.....	11 05 36	20	23	.....	.....	
		F_E.....	11 10 56	.....	.....	.....	.....	
15	.....	P_E.....	12 30 38	8	.....	.....	670	
		L_E.....	12 31 51	18	.....	.....	.....	
		M_E.....	12 32 07	18	29	.....	.....	
		P_N.....	12 31 00	10	.....	.....	460	
		L_N.....	12 31 51	12	.....	.....	.....	
		M_N.....	12 33 07	8	.....	19	.....	
		F_E.....	12 43 55	.....	.....	.....	.....	
		F_N.....	12 41 55	.....	.....	.....	.....	
19	.....	L_E.....	19 51 36	20	.....	.....	.....	N-S too small to measure.
		M_E.....	19 59 26	20	4	.....	.....	
		F_E.....	20 09 41	.....	.....	.....	.....	
22	.....	P.....	10 14 35	6	.....	.....	7,400	*East–West.*
		S.....	10 23 25	8	.....	.....	.....	
		L.....	10 26 35	20	.....	.....	.....	
		M.....	10 35 50	22	20	.....	.....	
		F.....	11 03 45	.....	.....	.....	.....	
		P.....	10 14 30	5	.....	.....	.....	*North–South.*
		L.....	10 29 25	20	.....	.....	.....	
		M.....	10 35 00	20	21	.....	.....	
26	.....	L_E.....	8 10 16	8	.....	.....	.....	
		M_E.....	8 16 36	12	8	.....	.....	
		M_N.....	8 16 16	12	.....	8	.....	
		F_E.....	8 21 15	.....	.....	.....	.....	
27	.....	P_E.....	14 58 59	10	.....	.....	.....	N-S too small to measure.
		M_E.....	15 22 13	20	7	.....	.....	
28	.....	L.....	23 09 11	25	.....	.....	.....	*East–West.*
		M.....	23 19 46	20	14	.....	.....	
		F.....	23 37 31	.....	.....	.....	.....	
		P.....	22 48 26	5	.....	.....	.....	*North–South.*
		L.....	23 13 11	25	.....	.....	.....	
		M.....	23 21 41	20	.....	14	.....	
		F.....	23 41 21	.....	.....	.....	.....	

No earthquakes were recorded during December, 1923, at the following stations:

COLORADO. *Regis College*, Denver.
DISTRICT OF COLUMBIA. *U. S. Weather Bureau*, Washington.
NEW YORK. *Fordham University*, New York.
VERMONT. *U. S. Weather Bureau*, Northfield.

Reports for December, 1923, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.
DISTRICT OF COLUMBIA. *Georgetown University*, Washington.
MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
CANADA. *Meteorological Service of Canada*, Toronto.

TABLE 3.—*Late reports (instrumental).*

CANADA. *Dominion Observatory, Ottawa.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 1	.....	e.....	20 16 06	.....	.....	.....	.....	New Zealand paper reports this quake as observed at Wellington, N. Z.
		eL....	20 16 37	.....	.....	.....	.....	
		M.....	20 17 54	12	12	.....	.....	
		L.....	20 20 ..	7	2.5	.....	.....	
		L.....	20 27 ..	7	1	.....	.....	
		F.....	20 58 ..	.....	.....	.....	.....	
2	.....	O.....	21 14 32	.....	.....	.....	10,040	Difficult record; P and eS uncertain
		Pv.....	21 27 36	.....	.....	.....	.....	
		eP.....	(21 28 24)	.....	.....	.....	.....	
		PR1..	(21 32 09)	.....	.....	.....	.....	
		PR2..	21 34 24	.....	.....	.....	.....	
		eS.....	21 38 36	.....	.....	.....	.....	
		SR1..	21 44 52	.....	.....	.....	.....	
		SR2..	21 49 11	.....	.....	.....	.....	
		eL....	21 58 30	.....	.....	.....	.....	
		M1....	22 19 30	18	72	.....	.....	
		M2....	22 25 42	17	63	.....	.....	
		M3....	22 28 30	17	50	.....	.....	
		M4....	22 30 ..	17	63	.....	.....	
		L.....	22 33 ..	17	.....	.....	.....	
		L.....	22 39 30	17	.....	.....	.....	
		L.....	23 07 ..	24	.....	.....	.....	
		L.....	23 16 ..	.....	.....	.....	.....	
3	.....	L.....	0 30 ..	.....	.....	.....	.....	
		F.....	1 *ca*..	.....	.....	.....	.....	
3	.....	eL....	3 41 ..	.....	.....	.....	.....	
		L.....	3 48 ..	20	0.5	.....	.....	Sinusoidal.
		F.....	4 02 ..	.....	.....	.....	.....	
3	.....	e?.....	5 43 ..	.....	.....	.....	.....	
		eL....	5 52 30	22	.....	.....	.....	
		L.....	6 03 30	20	2.5	.....	.....	Do.
		L.....	6 16 ..	15	.....	.....	.....	
		F.....	7 05 ..	.....	.....	.....	.....	
3	.....	O.....	8 37 43	.....	.....	.....	2,820	
		P.....	8 43 22	.....	.....	.....	.....	
		S.....	8 47 52	.....	.....	.....	.....	
		eL....	8 50 00	.....	.....	.....	.....	
		M.....	8 53 ..	20	.....	.....	.....	
		L.....	8 56 ..	16	.....	.....	.....	
		L.....	9 03 ..	12	.....	.....	.....	
		L.....	10 07 ..	.....	.....	.....	.....	
		F.....	10 35 *ca*.	.....	.....	.....	.....	
3	.....	e.....	16 44 28	.....	.....	.....	.....	
		e (S)..	16 56 00	.....	.....	.....	.....	
		eL....	17 05 ..	.....	.....	.....	.....	
		M1....	17 13 ..	30	30	.....	.....	
		M2....	17 19 ..	20	20	.....	.....	
		L.....	17 22 30	15	.....	.....	.....	
		L.....	17 34 ..	15	.....	.....	.....	
		L.....	18 20 ..	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Lost n micros.
4	.....	O.....	0 12 41	.....	.....	.....	9,000	
		P.....	0 24 54	.....	.....	.....	.....	
		PR2	0 30 12	.....	.....	.....	.....	
		e.....	0 31 49	.....	.....	.....	.....	
		S.....	0 35 04	.....	.....	.....	.....	
		SR1..	0 41 24	.....	.....	.....	.....	
		SR2..	0 45 28	.....	.....	.....	.....	
		eL....	0 55 ..	.....	.....	.....	.....	
		M1....	1 08 36	22	89	.....	.....	
		M2....	1 10 30	22	90	.....	.....	
		L.....	1 17 ..	19	.....	.....	.....	
		L.....	1 31 ..	15	.....	.....	.....	
		L.....	2 07 ..	15	.....	.....	.....	
		L.....	2 17 ..	15	.....	.....	.....	
		L.....	3 00 ..	.....	.....	.....	.....	Micros.
		F.....	.....	.....	.....	.....	.....	
4	.....	eL....	12 53 *to*	.....	.....	.....	.....	
		F.....	13 15 ..	.....	.....	.....	.....	
4	.....	e.....	20 33 30	.....	.....	.....	.....	
		e.....	20 40 56	.....	.....	.....	.....	
		e.....	20 49 15	.....	.....	.....	.....	
		eL....	21 01 45	.....	.....	.....	.....	
		L.....	21 06 ..	26	.....	.....	.....	
		M.....	21 10 ..	20	6	.....	.....	
		L.....	21 22 ..	20	.....	.....	.....	
		L.....	21 38 ..	16	.....	.....	.....	
		F.....	22 22 *ca*.	.....	.....	.....	.....	
4	.....	eL....	23 15 ..	.....	.....	.....	.....	
		L.....	23 24 ..	20	.....	.....	.....	
		F.....	23 45 ..	.....	.....	.....	.....	
5	.....	L.....	2 23 ..	22	.....	.....	.....	
		F.....	2 37 ..	.....	.....	.....	.....	
5	.....	eL....	14 37 ..	.....	.....	.....	.....	
		L.....	14 39 ..	29	.....	.....	.....	
		L.....	14 42 ..	16	.....	.....	.....	
		F.....	14 55 ..	.....	.....	.....	.....	
5	.....	O.....	21 29 07	.....	.....	.....	10,140	
		P.....	21 42 16	.....	.....	.....	.....	
		PRI..	21 46 13	.....	.....	.....	.....	
		PR21.	(21 48 18)	.....	.....	.....	.....	
		S	21 53 20	.....	.....	.....	.....	
		i.....	21 55 15	.....	.....	.....	.....	
		SR21..	22 04 30	.....	.....	.....	.....	

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 1		eL....	22 13 ..	.....	.....	.....	.....	
		M1....	22 16 00	44	185	.....	.....	
		M2....	22 22 24	28	50	.....	.....	
		M3....	22 27 30	24	35	.....	.....	
		L.....	22 35 30	16	.....	.....	.....	
		L.....	23 09 *to*	.....	.....	.....	.....	
		L.....	23 55 ..	16	.....	.....	.....	
6	.....	F.....	1 00 *ca*	.....	.....	.....	.....	
6	.....	i.....	17 38 08	.....	.....	.....	.....	Milne-Shaw only.
		L.....	17 53 ..	36	.....	.....	.....	
		L.....	18 00 ..	20	.....	.....	.....	
		F.....	19 35 *ca*	.....	.....	.....	.....	
6	.....	e.....	(20 00)	.....	.....	.....	.....	
		eL....	20 09 ..	36	.....	.....	.....	
		L.....	20 20 30	16	.....	.....	.....	
		F.....	21 12 *ca*	.....	.....	.....	.....	
7	.....	i.....	14 14 26	.....	.....	.....	.....	
		L.....	14 30 ..	.....	.....	.....	.....	
		L.....	14 40 ..	40	.....	.....	.....	
		L.....	14 47 ..	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Lost in changing sheets.
8	.....	O.....	0 01 48	.....	.....	.....	3,600	
		P.....	0 08 36	.....	.....	.....	.....	
		S.....	0 14 00	.....	.....	.....	.....	
		SR1?..	0 15 26	.....	.....	.....	.....	
		eL....	0 17 00	8	11	.....	.....	
		F.....	1 05 *ca*	.....	.....	.....	.....	
8	.....	e.....	20 45 30	.....	.....	.....	.....	Milne-Shaw No. 17 only. Sinusoidal.
		eL....	20 53 ..	.....	.....	.....	.....	
		L.....	20 56 30	20	.....	.....	.....	
		F.....	21 15 *ca*	.....	.....	.....	.....	
9	.....	O.....	3 22 43	.....	.....	.....	2,880	
		P.....	3 28 28	.....	.....	.....	.....	
		S.....	3 33 02	.....	.....	.....	.....	
		eL....	3 35 39	.....	.....	.....	.....	
		L.....	3 38 ..	.....	.....	.....	.....	
		L.....	3 40 ..	35	7	.....	.....	
		L.....	3 45 ..	.....	.....	.....	.....	
		F.....	4 45 *ca*	.....	.....	.....	.....	
10	.....	e.....	4 38 ..	.....	.....	.....	.....	
		eL....	4 43 ..	.....	.....	.....	.....	
		F.....	5 12 *ca*.	.....	.....	.....	.....	
10	.....	eL?...	22 00 ..	.....	.....	.....	.....	
		L.....	22 22 ..	20	.....	.....	.....	
		L.....	22 28 ..	18	.....	.....	.....	
		L.....	22 35 ..	16	.....	.....	.....	
		L.....	22 59 ..	12	.....	.....	.....	
		F.....	23 05 ..	.....	.....	.....	.....	
11	.....	e?.....	6 05 ..	.....	.....	.....	.....	May not be seismic.
		e.....	6 12 ..	.....	.....	.....	.....	
		F.....	6 15 ..	.....	.....	.....	.....	
11	.....	e.....	14 18 ..	.....	.....	.....	.....	
		eL....	14 21 ..	30	.....	.....	.....	
		L.....	14 26 ..	.....	.....	.....	.....	Periods irregular.
		F.....	14 40 ..	.....	.....	.....	.....	
12	.....	O.....	(11 56 21)	.....	.....	.....	(3, 580)	Phases doubtful.
		P?....	12 03 08	.....	.....	.....	.....	
		S?.....	12 08 30	.....	.....	.....	.....	
		SR2?..	12 10 38	.....	.....	.....	.....	
		eL?...	12 13 ..	.....	.....	.....	.....	
		L.....	12 20 ..	30	5	.....	.....	
		L.....	12 26 ..	15	.....	.....	.....	
		F.....	13 10 *ca*.	.....	.....	.....	.....	
16	.....	O.....	(4 15 22)	.....	.....	.....	(4, 120)	
		P?....	4 22 49	.....	.....	.....	.....	
		S.....	4 28 43	.....	.....	.....	.....	
		eL....	4 33 30	.....	.....	.....	.....	
		M1....	4 35 30	11	41	.....	.....	
		M2....	4 38 ..	10	21	.....	.....	
		L.....	4 47 ..	10	.....	.....	.....	
		L.....	4 56 ..	15	.....	.....	.....	
		F.....	5 25 *ca*.	.....	.....	.....	.....	
16	.....	eL....	7 26 18	.....	.....	.....	.....	
		L.....	7 27 15	12	.....	.....	.....	
		L.....	7 29 34	8	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Micros.
16	.....	eL....	19 26 ..	.....	.....	.....	.....	Faint; No. 17 only.
		L.....	19 30 ..	20	.....	.....	.....	Sinusoidal.
		L.....	19 48 30	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Micros.
17	.....	O.....	2 52 49	.....	.....	.....	7,120	
		P.....	3 03 23	.....	.....	.....	.....	
		PR2..	3 07 24	.....	.....	.....	.....	
		S.....	3 11 58	.....	.....	.....	.....	
		SR1...	3 16 46	.....	.....	.....	.....	
		SR2...	3 18 57	.....	.....	.....	.....	
		eL....	3 22 ..	40	5	.....	.....	
		M.....	3 32 30	16	14	.....	.....	
		L.....	3 39 ..	16	3	.....	.....	
		L.....	3 46 ..	16	.....	.....	.....	
		F.....	5 10 *ca*.	.....	.....	.....	.....	

TABLE 3.—*Late reports (instrumental)*—Continued.

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.		H. m. s.	Sec.	μ	μ	Km.		
18	.....	e.....	(21 48 18)	.....	.....	.....	.....	
		S?.....	21 57 39	.....	.....	.....	.....	
		SR1?..	22 03 12	.....	.....	.....	.....	
		eL.....	22 12 ..	.....	.....	.....	.....	
		L.....	22 18 30	.....	.....	.....	.....	
		L.....	22 27 ..	20	3	.....	.....	
		L.....	22 38 30	.....	.....	.....	.....	
		L.....	22 45 ..	15	.....	.....	.....	
		F.....	23 35 ..	.....	.....	.....	.....	
19	.....	eL.....	9 13 30	.....	.....	.....	.....	
		L.....	9 17 18	.....	.....	.....	.....	
		L.....	*to* 30 ..	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Micros.
22	.....	eL.....	8 19 ..	.....	.....	.....	.....	
		L.....	8 28 ..	18	1	.....	.....	Sinusoidal.
		L.....	8 33 ..	.....	.....	.....	.....	
		F.....	8 45 ..	.....	.....	.....	.....	
23	.....	e.....	3 22 ..	.....	.....	.....	.....	
		L.....	3 28 ..	24	.....	.....	.....	
		F.....	3 45 *ca.*	.....	.....	.....	.....	
25	.....	eL.....	(17 50)	.....	.....	.....	.....	No time marks.
		L.....	(17 55)	38	.....	.....	.....	
		L.....	(17 59)	30	.....	.....	.....	
		L.....	(18 06)	15	.....	.....	.....	
		F.....	(18 40)	.....	.....	.....	.....	
26	.....	e.....	(13 05)	.....	.....	.....	.....	Do.
		L.....	(13 26)	.....	.....	.....	.....	
		M.....	(13 37)	24	5	.....	.....	
		L.....	(14 07)	24	.....	.....	.....	
		F.....	(14 34)	.....	.....	.....	.....	
26	.....	e.....	16 26 00	.....	.....	.....	.....	
		eL.....	16 32 ..	.....	.....	.....	.....	
		F.....	16 42 ..	.....	.....	.....	.....	
28	.....	e?.....	0 40 ..	.....	.....	.....	.....	Small; sinusoidal.
		eL.....	0 49 ..	15	.....	.....	.....	
		F.....	1 00 *ca.*	.....	.....	.....	.....	

CANADA. *Meteorological Service of Canada, Toronto.*

1923.		H. m. s.	Sec.	μ	μ	Km.		
Nov. 1	.....	e.....	20 10 41	.....	.....	.....	.....	
		i.....	20 11 21	.....	.....	.....	.....	
		e.....	20 12 45	.....	.....	.....	.....	
		eL.....	20 14 45	.....	.....	.....	.....	
		L.....	20 15 57	.....	.....	.....	.....	
W		M.....	{20 16 06 / 20 16 11}	10	.....	16	.....	Marked micros interfere with early phases.
		i.....	20 18 37	8	.....	.....	.....	
		L.....	20 19 23	13	.....	.....	.....	
		F.....	21 02 00	.....	.....	.....	.....	
		S.....	20 12 41	.....	.....	.....	.....	
		e.....	20 15 15	.....	.....	.....	.....	
N		eL.....	20 15 38	.....	.....	.....	.....	
		L.....	20 16 00	10	.....	.....	.....	
			to					
			20 18 23	.....	.....	.....	.....	Micros masked P waves.
		M.....	{20 16 00 / 20 16 10}	.....	9	.....	.....	
		L.....	20 19 15	.....	.....	.....	.....	
		F.....	Micros.	.....	.....	.....	.....	
2	.....	eP.....	21 27 41	.....	.....	.....	.....	P doubtful owing to small micros. P undulatory.
		PR1..	21 34 13	.....	.....	.....	.....	
		eS.....	21 38 30	.....	.....	.....	.....	
		i.....	21 38 35	.....	.....	.....	.....	
W		SR.....	21 44 38	.....	.....	.....	.....	
		iSR.....	21 46 30	.....	.....	.....	9,800	
		eL.....	22 02 29	.....	.....	.....	.....	
		L.....	22 07 00	26 to	.....	.....	.....	
			to					
			22 14 10	30	.....	.....	.....	
		L.....	22 16 13	15	.....	.....	.....	Uniform.
			to	to				
			22 23 15	19	.....	84	.....	
		M.....	22 19 04	17	.....	.....	.....	
		L.....	22 23 39	.....	.....	.....	.....	
		F.....	1 30 00	.....	.....	.....	.....	
		P.....	21 27 45	.....	.....	.....	.....	
		S.....	21 38 30	.....	.....	.....	.....	
		i.....	21 45 08	.....	.....	.....	.....	
		L.....	21 59 00	?45	.....	.....	.....	
N		eL.....	22 03 00	slow.	.....	.....	.....	
		L.....	22 07 15	.....	.....	.....	.....	
			to					
			22 20 53	.....	.....	.....	.....	Uniform.
		M1....	22 09 55	.....	30	.....	.....	
		M2....	22 10 17	23	.....	.....	.....	
		L.....	22 23 30	18	.....	.....	9,720	
		L.....	22 43 15	18	.....	.....	.....	
		F.....	23 56 ..	.....	.....	.....	.....	
3	.....	eL.....	3 29 24	.....	.....	.....	.....	
W		L.....	3 38 10	.....	.....	.....	.....	Small amplitude. N-S component, nothing.

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1923.		H.m.s.	Sec.	μ	μ	Km.		
Nov. 3	.....	L.....	5 06 28	.....	.....	.....	.....	N-S component nothing.
W		L.....	5 16 30	.....	.....	.....	.....	
		F.....	5 34 00	.....	.....	.....	.....	Small slow waves.
3	.....	e.....	5 44 30	.....	.....	.....	.....	
W		e.....	5 48 08	.....	.....	.....	.....	N-S component not affected.
			5 49 03	22	.....	.....	.....	Sinusoidal
			to	to				
			6 03 00	25	.....	9	.....	
		L.....	6 07 34	20	.....	.....	.....	
		F.....	6 36 00	.....	.....	.....	.....	
3	.....	O.....	8 37 21	.....	.....	.....	.....	
		eP.....	8 43 07	.....	.....	.....	.....	
		iS.....	8 47 42	.....	.....	.....	.....	
W		i.....	8 47 52	15	.....	24	.....	Larger amplitude at beginning than in principal part.
		iSR....	8 48 41	.....	.....	.....	.....	
		eL.....	8 50 06	.....	.....	.....	.....	
		L.....	8 50 56	21	.....	.....	.....	Sinusoidal.
			8 53 15	.....	.....	.....	2,890	
			8 55 47	.....	.....	.....	.....	
			to					
			9 29 15	.....	.....	.....	.....	
		M1.....	{8 55 58 / 8 56 08}	15	.....	23	.....	
		M2.....	8 56 13	.....	.....	.....	.....	
		F.....	?10 52 ..	.....	.....	.....	.....	
		iP.....	8 43 09	3 to 8	7	.....	.....	P and S sharp and well defined.
		i.....	8 47 30	.....	.....	.....	.....	
		iS.....	8 47 43	6	7	.....	.....	
N		eL.....	8 51 41	.....	.....	.....	.....	
		L.....	8 56 36	12	.....	.....	.....	Possibly West Indies.
		M1.....	8 58 15	10	.....	.....	.....	
		M2.....	8 59 38	10	9	.....	2,880	
		F.....	10 35 00	.....	.....	.....	.....	
3	.....	eL.....	16 38 43	.....	.....	.....	.....	Uniform waves, micros going on, may not be seismic.
		e?.....	16 39 52	9	.....	.....	.....	
		e.....	16 44 10	.....	.....	.....	.....	
		e.....	16 45 10	.....	.....	.....	.....	
		e.....	16 56 15	.....	.....	.....	.....	
		eL.....	17 00 32	.....	.....	.....	.....	
W		L.....	17 04 38	.....	.....	.....	.....	
		L.....	17 15 11	23	.....	.....	.....	
		M1.....	17 19 38	.....	.....	.....	.....	
		M2.....	17 20 00	22	.....	27	.....	
		F.....	Micros.	.....	.....	.....	.....	
		i.....	16 44 10	.....	.....	.....	.....	Small amplitude micros going on.
N		L.....	17 15 38	26	.....	.....	.....	
		L.....	17 24 53	.....	.....	.....	.....	
		F.....	?17 46 00	.....	.....	.....	.....	
4	.....	P.....	0 23 56	8 to 10	.....	.....	.....	
		e.....	0 24 58	15	.....	.....	.....	Micros going on.
		PR.....	0 30 10	.....	.....	.....	.....	
		i.....	0 31 35	15	.....	.....	.....	
		eS.....	0 34 46	.....	.....	.....	.....	
		iSR1..	0 41 28	.....	.....	.....	.....	
		SR.....	0 42 13	.....	.....	.....	.....	
W		L.....	0 54 52	19	.....	.....	.....	
		L.....	0 57 51	30	.....	.....	.....	Uniform waves.
		M.....	{1 05 24 / 1 05 51}	26	.....	281	.....	
		L.....	1 25 53	17	.....	.....	.....	
		F.....	Micros.	.....	.....	.....	.....	
		P.....	0 23 53	.....	.....	.....	.....	
		e.....	0 34 30	.....	.....	.....	.....	
		eS.....	0 34 50	.....	.....	.....	.....	
N		L.....	0 54 15	.....	.....	.....	.....	
		L.....	1 03 00	28	.....	.....	.....	P doubtful owing to micros.
			1 09 00	25	.....	.....	.....	
		M1.....	1 05 11	.....	53	.....	.....	Sinusoidal.
		M2.....	1 05 38	27	.....	.....	.....	
		F.....	2 12 00	.....	.....	.....	.....	
4	.....	eL.....	12 54 53	.....	.....	.....	.....	Nothing on N-S component.
W		F.....	Micros.	.....	.....	.....	.....	Small amplitude.
4	.....	e.....	20 32 36	.....	.....	.....	.....	
		L.....	21 00 30	.....	.....	.....	.....	
W		L.....	21 02 30	30	.....	.....	.....	
			to					
			21 17 38	25 to 15	12	.....	.....	Micros going on.
			and from					
			21 18 38	.....	.....	.....	.....	
			to					
			21 23 ..	17	.....	.....	.....	
		F.....	23 59 ..	.....	.....	.....	.....	N-S component, very little affected.
5	.....	e.....	2 22 15	.....	.....	.....	.....	Nothing on N-S component.
		eL.....	2 24 38	23	.....	.....	.....	
W		F.....	?2 34 ..	.....	.....	.....	.....	
5	.....	e.....	14 36 30	.....	.....	.....	.....	
		eL.....	14 38 38	30	.....	.....	.....	
W		L.....	14 40 00	23	5	.....	.....	
		F.....	14 52 00	.....	.....	.....	.....	
		L.....	14 42 23	.....	.....	.....	.....	Very little affected.
N		F.....	14 58 00	.....	.....	.....	.....	

TABLE 3.—*Late reports (instrumental)*—Continued.

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1923.								
Nov. 5	.....	H. m. s.	Sec. 7	μ	μ	Km.	.....	
		O.....	21 29 18	.....	.....	.....	.....	
		P?.....	?21 42 06	.....	.....	.....	.....	P, poorly defined.
		iS.....	21 52 53	.....	.....	.....	.....	
		e.....	21 53 42	.....	.....	.....	.....	
		eL.....	22 11 35	22	.....	.....	.....	
W		L.....	22 17 23	.....	.....	.....	9,780	
		M1.....	22 19 48	} 33	.....	94	.....	
			?22 20 05					
		M2.....	22 28 18	23	.....	50	.....	
		L.....	23 13 00	15	.....	.....	.....	
		F.....	1 02 00	.....	.....	.....	.....	
		P?.....	?21 42 08	.....	.....	.....	.....	P, ill defined.
		iS.....	21 52 55	.....	.....	.....	.....	
N		L.....	21 14 25	.....	.....	.....	.....	Sinusoidal waves.
			21 24 15	30	.....	.....	.....	
			21 28 45	.....	.....	.....	9,760	
			again					
			21 30 00	20 to 23	.....	.....	.....	
			21 37 23	.....	.....	.....	.....	
		M1.....	21 27 12	23	57	.....	.....	
		M2.....	21 27 33	23	57	.....	.....	
		F.....	1 00 00	.....	.....	.....	.....	
6	.....	e.....	17 37 50	8	.....	.....	.....	
		eL.....	17 49 38	.....	.....	.....	.....	Small amplitude.
W		F.....	19 24 00	.....	.....	.....	.....	
		e.....	17 37 52	.....	.....	.....	.....	
		i.....	17 38 10	.....	.....	.....	.....	
N	.....	L.....	18 02 15	.....	.....	.....	.....	
		F.....	18 30 00	.....	.....	.....	.....	
6	.....	L.....	20 11 30	.....	.....	.....	.....	
W		L.....	20 19 08	23	.....	.....	.....	Small amplitude.
		F.....	21 10 00	.....	.....	.....	.....	
		eL.....	20 16 40	.....	.....	.....	.....	
N		L.....	20 18 15	.....	.....	.....	.....	
			20 24 45	.....	.....	.....	.....	Sinusoidal.
			20 27 15	15	4	.....	.....	
		F.....	21 07 00	.....	.....	.....	.....	
8	.....	P.....	?0 08 35	.....	.....	.....	.....	
		iS.....	0 13 00	.....	.....	.....	.....	
		i.....	0 15 17	11	.....	.....	.....	
		L.....	0 16 00	8	.....	.....	.....	
W		M1.....	0 15 21	.....	.....	.....	.....	Quake reported from Calexico, Calif. Masked by local causes.
		M2.....	0 15 32	.....	.....	17	.....	
		F.....	.....	.....	.....	.....	.....	
		e.....	0 10 39	.....	.....	.....	.....	
		e.....	0 12 18	.....	.....	.....	.....	
		i.....	0 12 47	.....	.....	.....	.....	
		iS.....	0 13 04	.....	.....	.....	.....	
		L.....	0 14 43	8 to 11	.....	.....	.....	
		M.....	0 13 23	?10	17	.....	.....	
N		M2.....	0 15 00	8	12	.....	.....	
		F.....	1 06 00	.....	.....	.....	.....	
9	.....	P.....	Micros..	.....	.....	.....	.....	N–S component hardly affected.
		eS.....	3 32 08	.....	.....	.....	.....	
		e.....	3 34 15	.....	.....	.....	.....	
W		L.....	3 40 35	.....	.....	.....	.....	
		L.....	3 42 00	15	.....	.....	.....	
		M.....	3 42 30	.....	.....	9	.....	
		F.....	4 50 00	.....	.....	.....	.....	
10	.....	e.....	3 14 15	12	.....	.....	.....	May not be seismic. Nothing on N–S component.
12	.....	e.....	?12 00 26	.....	.....	.....	.....	N–S component, barely affected.
		e.....	12 08 21	.....	.....	.....	.....	
		iS.....	12 08 29	.....	.....	.....	.....	Faint at 12 01 00, on bands.
		SR.....	12 10 30	.....	.....	.....	.....	
W		eL.....	12 21 23	.....	.....	.....	.....	
		L.....	12 24 12	15	.....	.....	.....	
		M.....	12 27 00	.....	.....	6	.....	
		F.....	13 14 00	.....	.....	.....	.....	
16	.....	eS.....	4 28 28	.....	.....	.....	.....	
		i.....	4 32 20	.....	.....	.....	.....	Micros mask P.
W		L.....	4 32 30	11 to 15	.....	.....	.....	
		iL.....	4 34 14	.....	.....	.....	.....	
			4 34 47	.....	.....	.....	.....	Sinusoidal.
			to					
			4 36 00	14	.....	.....	.....	
		M1.....	4 34 51	.....	.....	.....	.....	
		M2.....	4 35 04	13	.....	50	.....	
		iL.....	4 36 45	.....	.....	.....	.....	
		iL.....	4 37 30	.....	.....	.....	.....	
		F.....	5 30 ..	.....	.....	.....	.....	
		P.....	Micros..	.....	.....	.....	.....	
		S.....	4 28 15	.....	.....	.....	.....	Small micros going on.
		L.....	4 33 30	.....	.....	.....	.....	
N		iL.....	4 34 30	.....	.....	.....	.....	L superimposed on marked reflected waves,
		M1.....	4 34 49	.....	.....	.....	.....	
		M2.....	4 35 02	.....	.....	.....	.....	
		M3.....	4 35 15	11	16	.....	.....	
		F.....	Micros..	.....	.....	.....	.....	

CANADA. *Meteorological Service of Canada, Toronto*—Continued.

1923.								
Nov. 16	.....	H. m. s.	Sec.	μ	μ	Km.	.....	
		L.....	7 26 33	13	.....	.....	.....	
		L.....	7 26 49	15	5	.....	.....	
		L.....	7 28 30	15	.....	.....	.....	
W		i.....	7 29 17	8	.....	.....	.....	
		F.....	7 40 ..	.....	.....	.....	.....	
		L.....	7 26 45	.....	.....	.....	.....	Micros going on.
N		i.....	7 30 35	.....	.....	.....	.....	
		F.....	?7 34 ..	.....	.....	.....	.....	Very small amplitude.
17	.....	eP.....	3 03 36	.....	.....	.....	.....	
		eS.....	3 11 55	}	.....	.....	.....	
		iS.....	3 11 57		.....	.....	.....	
W		eL.....	3 22 35	.....	.....	.....	.....	
		M.....	3 30 10	.....	.....	.....	.....	
		M.....	3 32 00	18	.....	14	.....	
		F.....	5 16 00	.....	.....	.....	.....	
		iP.....	3 03 33	5	.....	.....	.....	
		S.....	3 11 49	}	.....	.....	.....	
		eS.....	3 12 09		.....	.....	.....	Very faint marking at 3h. 01m. 49s.
N		iSR1..	3 13 23	.....	.....	.....	.....	
		eL.....	3 22 30	.....	.....	.....	.....	
		i.....	3 28 20	.....	.....	.....	.....	
		L.....	3 30 23	15 to 20	.....	.....	.....	Sinusoidal.
			to					
			3 34 53	.....	7	.....	.....	
		L.....	3 35 45	23	.....	.....	.....	
		L.....	3 42 26	15	.....	.....	.....	
		F.....	4 42 ..	.....	.....	.....	.....	
18	.....	L.....	22 06 30	.....	.....	.....	.....	Early phases masked by micros.
		L.....	22 22 45	.....	.....	.....	.....	
W		L.....	22 34 15	.....	.....	.....	.....	
		L.....	22 34 43	23	.....	13	.....	
		F.....	Micros..	.....	.....	.....	.....	
		L.....	22 32 49	.....	.....	.....	.....	Slow waves small amplitude.
N		L.....	22 41 00	.....	.....	.....	.....	
		F.....	22 52 00	.....	.....	.....	.....	
19	.....	L.....	9 12 15	.....	.....	.....	.....	Strong micros prevailing. N–S component, nothing discernible, small micros going on.
W		L.....	9 18 45	.....	.....	.....	.....	
		F.....	Micros..	.....	.....	.....	.....	
23	.....	L.....	3 27 23	.....	.....	.....	.....	N–S component, nothing.
W		F.....	3 40 00	.....	.....	.....	.....	Nothing marked.
25	.....	L.....	17 44 48	.....	.....	.....	.....	Slow waves.
W		eL.....	17 57 38	30	.....	.....	.....	Continuous slow waves.
		L.....	18 00 19	23	.....	.....	.....	Small amplitude.
			18 13 00	.....	.....	.....	.....	
		F.....	18 53 00	.....	.....	.....	.....	
		L.....	18 06 19	18	.....	.....	.....	Preceded by marked micros.
N		L.....	18 15 00	18	.....	.....	.....	
		F.....	18 20 00	.....	.....	.....	.....	
26	.....	e.....	13 28 23	.....	.....	.....	.....	Micros going on.
		L.....	13 35 08	.....	.....	.....	.....	
W		L.....	13 46 56	19	.....	.....	.....	Undulatory, small amplitude.
		L.....	14 03 35	.....	.....	.....	.....	
		F.....	14 40 ..	.....	.....	.....	.....	
		L.....	13 36 52	.....	.....	.....	.....	
		L.....	13 40 20	.....	.....	.....	.....	
N		L.....	14 06 38	.....	.....	.....	.....	Very small amplitude.
		F.....	14 12 ..	.....	.....	.....	.....	
26	.....	e.....	16 28 47	.....	.....	.....	.....	Micros going on.
		eL.....	16 31 55	15	.....	.....	.....	Small amplitude.
W		F.....	Micros..	.....	.....	.....	.....	
		L.....	16 33 36	.....	.....	.....	.....	
		L.....	16 36 15	.....	.....	.....	.....	
N		.....	.....	15	.....	.....	.....	Very small amplitude. Uniform waves.
			16 38 45	.....	.....	.....	.....	
		F.....	16 42 ..	.....	.....	.....	.....	
28	.....	L.....	0 42 15	.....	.....	.....	.....	Micros going on, but does not show any eq. effect.
		L.....	0 49 15	.....	.....	.....	.....	Small amplitude.
W		L.....	0 51 36	15	.....	.....	.....	
		F.....	Micros..	.....	.....	.....	.....	
N		.....	.....	.....	.....	.....	.....	.....

NEW YORK. *Cornell University, Ithaca.*

1923.							
May 31	.....	H. m. s.	Sec.	μ	μ	Km.	
		e.....	22 17 30	.....	.....	.....	.....
		eL.....	22 20 30	.....	.....	.....	.....
		F.....	22 30 ..	.....	.....	.....	.....

TABLE 3.—*Late reports (instrumental)*—Continued.

NEW YORK. *Cornell University, Ithaca*—Continued.

1923. June 1		e	17 48 18					
		e	17 55 ..					
		e	18 04 ..					
		L	18 13 ..	20				
		L	18 16 ..	25				
		L	18 20 ..	22				
		F	19 05 ..					
1		e	20 38 36					
		i	20 39 36					
		L	21 07 ..	20				
		L	21 13 ..	20				
		F	21 31 ..					
18		e	8 40 30					
		i	8 41 42					
		e	8 49 ..					
		L	9 04 ..	20				
		L	9 12 ..	20				
		F	9 32 ..					
19		i	22 52 08					
		eS	22 59 ..					
		e	23 03 30					
		L	23 07 ..					
		M	23 09 ..					
		F	23 41 ..					
22		e	4 06 ..					
		F	4 17 ..					
22		e	7 04 ..					
		e	7 06 30					
		e	7 09 42					
		e	7 11 ..					
		e	7 14 42					
		e	7 20 ..					
		L	7 42 ..	28				
		L	8 01 ..	17				
		F	8 33 ..					
July 13		eL	11 59 ..					
		L	12 13 ..					
		L	12 59 ..					
		F	13 11 ..					
22		eP	14 29 ..					Time marker out of order.
		S	14 38 ..					
		L	14 50 ..					
		L	14 55 ..	20				
		F	15 45 ..					
23		e	7 44 ..					
		i	7 47 55					
		M	7 48 30					
		F	8 03 ..					
Aug. 8		i	12 08 07					
		e	12 09 19					
		e	12 13 ..					
		e	12 15 27					
		L	12 20 ..					
		F	12 26 ..					
28		P	23 21 41					
		S	23 26 40					
		e	23 28 14					
		e	23 29 ..					
		L	23 31 ..	30				
		M	23 33 ..	13				
29		F	0 39 ..					
Sept. 1		eP	3 11 59					
		PR1	3 15 40					
		PR3	3 19 40					
		S	3 22 44					
		SR1	3 29 12					
		L	3 39 ..	70				
		L	3 47 ..	32				
		M	3 54 ..	20				
		L	3 59 ..	20				
		L	4 50 ..	15				
		F	6 27 ..					
2		e	3 04 00					
		e	3 07 48					
		S	3 10 36					
		e	3 17 48	18				
		L	3 26 ..	18				
		L	3 36 ..	20				
		L	3 47 36	21				
		F	4 52 ..					
2		e	9 51 ..					
		L	10 26 ..	20				
		F	10 42 ..					
9		e	22 32 ..					
		e	22 38 ..					
		L	22 56 ..					
		L	22 59 ..	30				
		L	23 14 ..	20				
		F	23 37 ..					

NEW YORK. *Cornell University, Ithaca*—Continued.

1923. Sept. 22		e	12 50 ..					
		F	13 01 ..					
22		e	21 04 30					
		e	21 11 42					
		e	21 15 ..					
		e	21 21 ..					
		L	21 33 ..					
		L	21 39 ..	20				
		L	21 47 ..	20				
		F	22 13 ..					
26		e	9 01 30					
		L	9 16 ..	24				
		F	9 37 ..					
30		eP	1 27 ..					
		S	1 31 42					
		L	1 33 12	26				
		M	1 38 18	16				
		F	3 09 ..					
Oct. 7		e	3 52 ..					
		i	3 52 24					
		e	4 04 30					
		L	4 25 ..					
		L	4 30 ..	24				
		L	4 37 ..	26				
		L	4 44 ..	23				
		F	5 43 ..					
10		P	7 19 20					
		e	7 20 47					
		i	7 21 21					
		S	7 25 36					
		eL	7 31 ..					
		L	7 35 ..	18				
		F	8 10 ..					
13		L	4 47 30					
		F	4 59 ..					
Nov. 1		e	20 14 ..					
		L	20 16 ..	12				
		F	20 30 ..					
2		eP	21 28 52					
		S	21 39 ..					
		e	21 45 30					
		L	22 04 ..	28				
		L	22 08 ..	28				
		L	22 19 30	18				
		L	22 33 ..	18				
		F	23 43 ..					
3		P	8 42 57					
		S	8 47 07					
		eL	8 49 30	19				
		L	8 54 ..	16				
		L	9 13 ..	12				
		F	9 30 ..					
3		i	16 44 21					
		L	17 17 ..	26				
		L	17 22 ..	21				
		F	17 40 ..					
4		P	0 24 50					
		eL	0 55 ..	28				
		L	1 03 ..	33				
		F	1 53 ..					
5		eP	21 46 ..					
		eS	21 56 ..					
		eL	22 13 ..					
		L	22 24 ..					
		L	22 27 ..	26				
		L	22 31 ..	22				
		F	23 01 ..					
8		e	0 13 30					Short period waves; M between 0:14 and 0:15.
		e	0 16 12					
		F	0 27 ..					
9		e	3 40 ..					Short periods.
		F	3 52 ..					
16		L	4 35 ..					
		L	4 39 ..					
		F	4 48 ..					
17		e	3 12 18					
		i	3 13 40					
		L	3 28 ..	20				
		F	3 51 ..					
18		L	22 37 ..	20				
		F	22 46 ..					

EARTHQUAKES FELT IN THE UNITED STATES DURING 1923.

(Consult also Chart XIV in this issue.)

By EDGAR W. WOOLARD.

During the calendar year 1923, 76 separate earthquakes strong enough to be felt by the unaided senses were reported from different parts of the continental United States, as listed in the accompanying table and graphically represented (a dot for each *report*, not for each separate quake) on Chart XIV at the end of this issue of the REVIEW.

Earthquakes of reported intensity 5 or greater (adapted Rossi-Forel scale) occurred in Arkansas, October 28 and November 26; in California on January 22, May 4, July 23, 20, and 22, August 25, and November 5 and 28; in Oregon, January 11; in Tennessee, October 28; in Texas, March 7; in Utah, May 14; and in Wyoming, March 24. The Californian quake of January 22 was accompanied by considerable damage in some places; this disturbance was well recorded on numerous distant seismographs. The Californian quakes of July 23 and October 5 also caused some damage in places; the remainder of the tremors reported produced little or no destruction. Widespread, but in general faint, shocks occurred on October 28 in Alabama, Arkansas, Illinois, Kentucky, Mississippi, and Missouri; on November 26 in Tennessee and Arkansas; and in the early hours of the year 1924 (Greenwich time) in Mississippi, South Carolina, Tennessee, Kentucky, Illinois, and Arkansas.

An earthquake of marked intensity occurred under the Pacific Ocean on February 4, severing the cable between Guam and the Midway Islands and causing destructive seawaves in Hilo Harbor, Hawaii. No other important quakes occurred in our outlying possessions during 1923.

Places in the United States reporting earthquakes during 1923.

(Consult also Chart XIV in this issue.)

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
ARIZONA.			
Gisela	34 10	111 00	1
Pine	34 20	111 25	1
Roosevelt	33 40	111 00	1
Payson	34 10	111 00	1
Yuma	32 40	114 35	2
ALABAMA.			
Riverton	34 55	88.05	1
ARKANSAS.			
Arkansas City	33 50	91 05	1
Brinkley	34 55	91 05	1
Corning	36 35	90 30	1
Eureka Springs	36 30	93 50	1
Helena	34 30	90 30	1
Jonesboro	35 55	90 35	1
Little Rock	34 40	92 05	1
Marianna	34 45	90 40	1
Marked Tree	35 30	90 25	2
Osceola	35 45	90 00	1
Stuttgart	34 30	91 30	1
Wilson	35 37	90 00	1
Wynne	35 15	90 45	2
CALIFORNIA.			
Alton	40 30	120 40	1
Arrowheat Springs	34 20	117 15	2
Avalon	33 15	118 15	1
Balboa	33 50	117 50	1
Barrett	32 30	116 45	1
Brawley	32 59	115 40	2
Calexico	32 41	115 30	7
Camptonville	39 30	121 00	1
Cedarville	41 30	120 05	1
Chico	39 45	121 50	1
Chula Vista	32 30	117 10	2
Cholame	35 35	120 10	1
Claremont	37 48	122 26	1
Cloverdale	38 45	123 00	1
Compton	33 55	118 15	2
Calipatria	33 08	115 30	1
Dyerville	40 20	124 00	1
Elsinore	33 37	117 15	1

Places in the United States reporting earthquakes during 1923—Con.

(Consult also Chart XIV in this issue.)

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
CALIFORNIA—continued.			
Eureka	40 48	124 10	5
Fairmont	34 45	118 30	1
Ferndale	40 30	124 20	1
Fontana	34 05	116 30	1
Fort Bragg	39 30	123 50	1
Fort Ross	38 30	123 15	1
Highlands	34 10	117 15	1
Julian	33 05	116 37	1
Lakeport	39 03	122 56	2
Llano	34 30	117 47	1
Loleta	40 40	124 15	1
Long Beach	33 45	118 15	1
Los Alamos	34 45	120 15	1
Los Angeles	34 03	118 15	2
Los Gatos	37 12	121 58	1
McCloud	41 15	122 10	1
Mt. Wilson	34 13	118 16	1
Nevada City	39 15	121 00	2
Ojai	34 25	119 12	1
Orland	39 45	122 15	1
Oxnard	34 15	119 15	1
Pasadena	34 05	118 10	1
Pepperwood	40 30	124 00	1
Petrolia	40 15	124 20	1
Pomona	34 05	117 45	1
Red Bluff	40 10	122 15	1
Redding	40 35	122 25	1
Rialto	34 05	117 30	1
Salinas	36 41	121 39	1
San Bernardino	34 05	117 15	2
San Diego	32 43	117 10	4
San Luis Obispo	35 13	120 45	1
Santa Maria			1
Santa Rosa	38 30	122 45	3
Scotia	40 30	124 05	1
Sierra Madre	34 15	118 10	1
Spreckels	36 38	121 36	1
Susanville	40 30	120 40	1
Trona	35 45	117 20	1
Tustin	33 45	117 50	1
Upper Mattole	40 15	124 15	4
Valley Center	33 15	117 00	2
Willows	34 03	118 15	1
Yorba Linda	33 50	117 45	2
ILLINOIS.			
Cairo	37 00	89 05	4
Greenville	38 50	89 20	1
KENTUCKY.			
Calhoun			1
Hickman	36 34	89 12	1
Wickliffe	37 00	89 05	2
MISSISSIPPI.			
Corinth	35 00	88 25	1
Wyatte	34 35	89 45	1
MONTANA.			
Helena	46 40	112 00	3
MISSOURI.			
Poplar Bluff	36 50	90 25	1
NEW JERSEY.			
Ventnor	39 20	74 25	1
NEW MEXICO.			
Columbus	32 00	107 40	1
OREGON.			
Lakeview	42 10	120 20	1
Valley Falls	42 20	120 20	1
SOUTH CAROLINA.			
Charleston	32 45	80 00	2
Due West	34 15	82 30	1
Summerville	33 05	80 15	1
TENNESSEE.			
Memphis	35 10	90 00	2
Savannah	35 15	88 15	1
TEXAS.			
Sierra Blanca	31 10	105 25	1
El Paso	31 45	106 30	1
UTAH.			
Nada	38 10	113 15	1
Richmond	41 55	112 10	1
WASHINGTON.			
Anacortes	48 30	122 40	1
Marietta	48 50	122 40	1
Olga	48 40	122 50	1
Silverton	48 05	121 40	1
Arlington	48 10	122 10	2
WYOMING.			
Bighorn	44 40	107 00	1
Elk	43 50	110 30	1
Kelly	43 40	110 40	1
Kendall	43 10	110 00	1
South Pass City	42 30	108 50	1

(Plotted by Wilfred P. Day.)

(Inset) Departure of Monthly Mean Pressure from Normal.

(Plotted by Wilfred P. Day.)

Chart II. Tracks of Centers of Cyclones, December, 1923. (Inset) **Change in Mean Pressure from Preceding Month.**

(Plotted by Wilfred P. Day.)

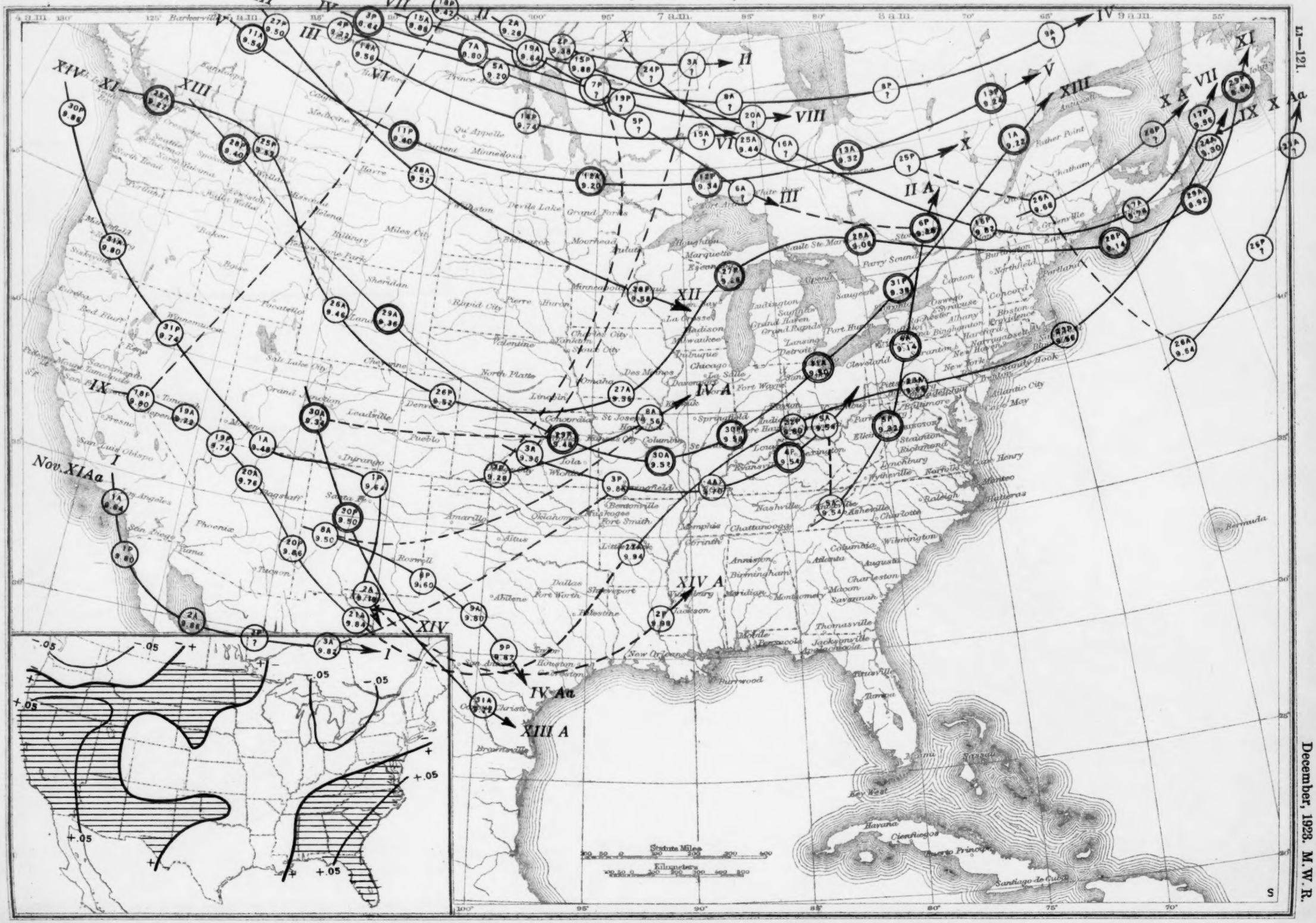


Chart III. Departure (°F.) of the Mean Temperature from the Normal, December, 1923.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, December, 1923.

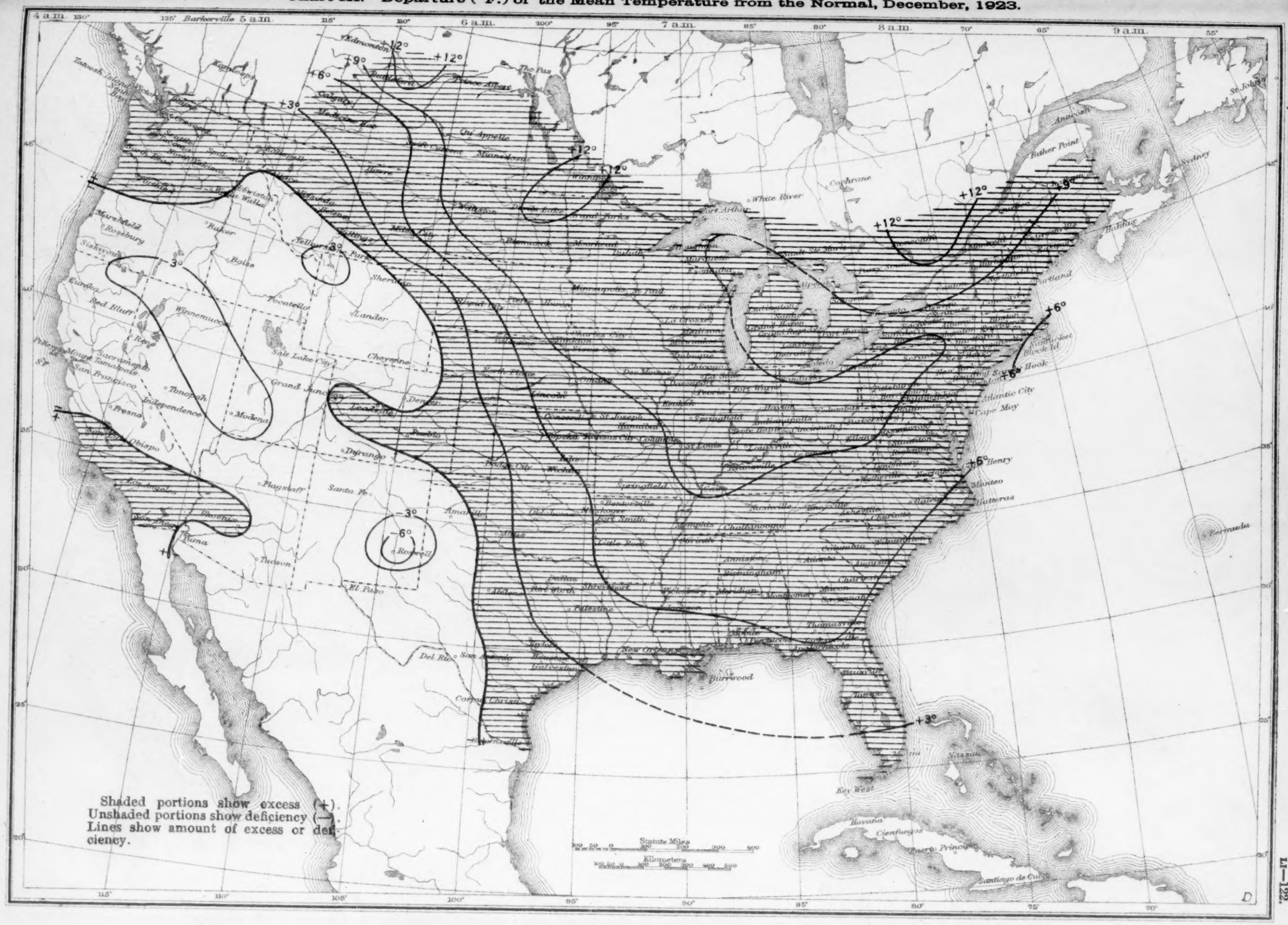
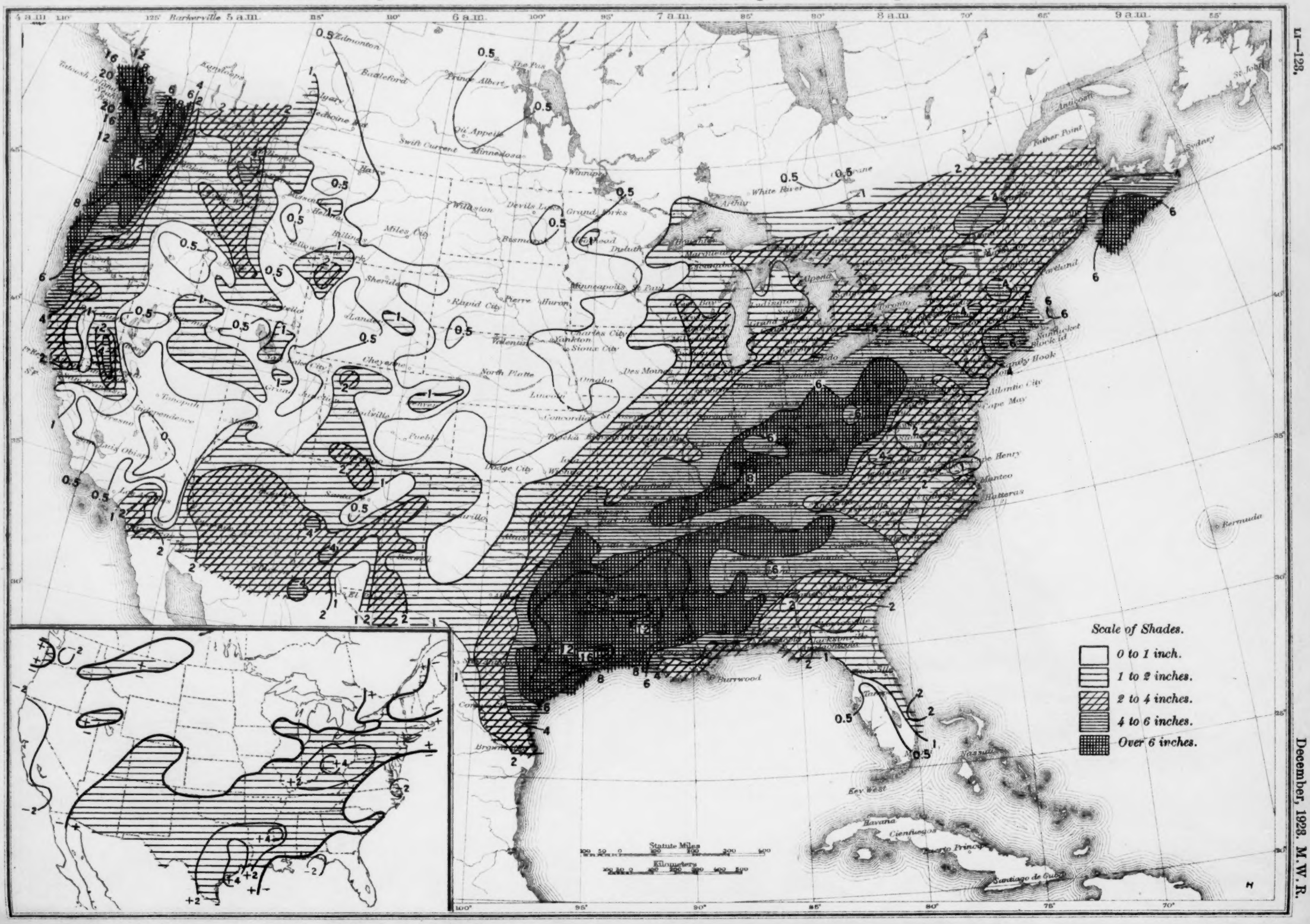


Chart IV. Total Precipitation, Inches, December, 1923. (Inset) **Departure of Precipitation from Normal.**



December, 1923. M. W. R.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, December, 1923.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, December, 1923.

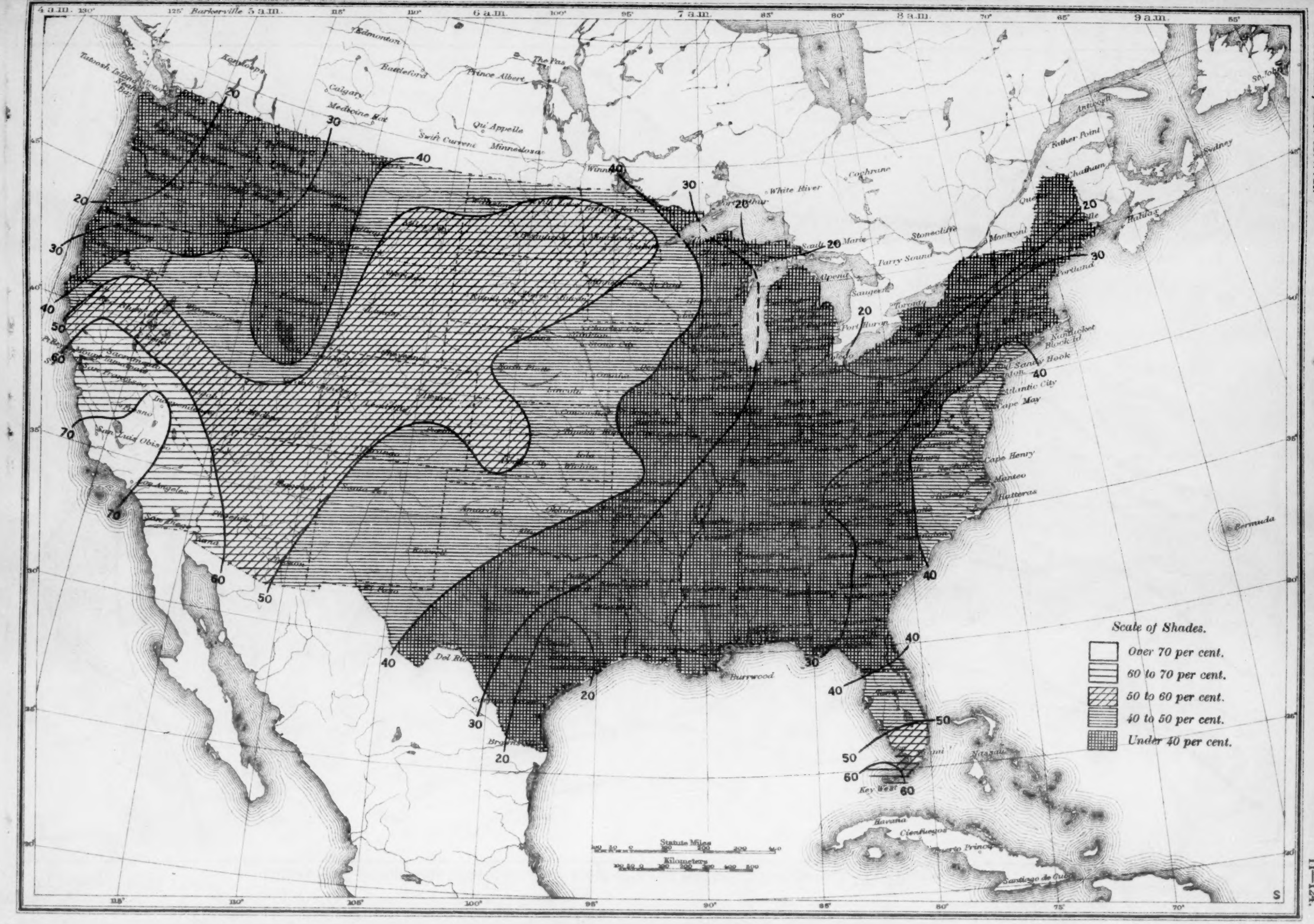


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, December, 1923.

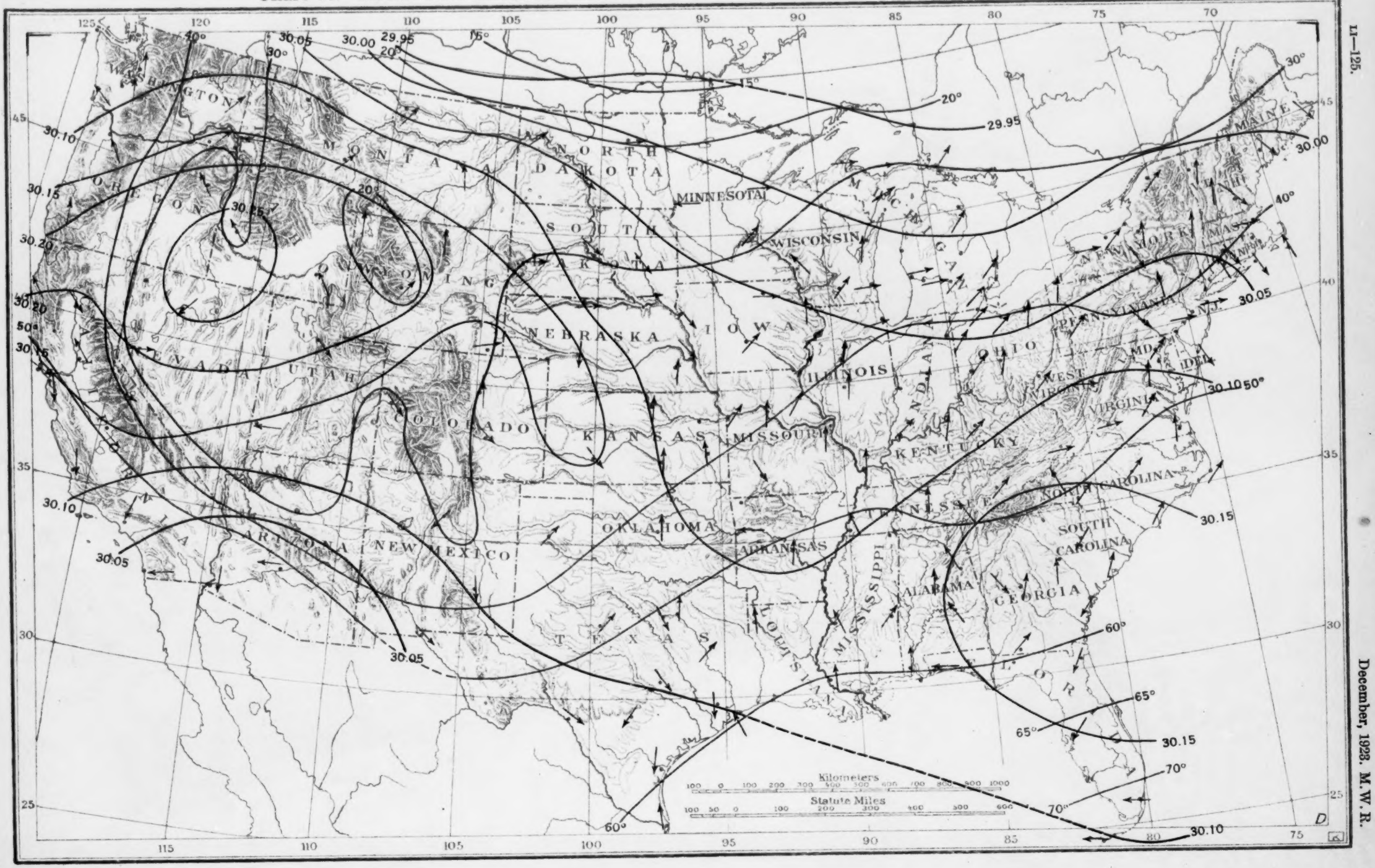


Chart VII. Total Snowfall, Inches, December, 1923. (Inset) Depth of Snow on Ground at end of Month.

Chart VII. Total Snowfall, Inches, December, 1923. (Inset) Depth of Snow on Ground at end of Month.

Chart VIII. Weather Map of North Atlantic Ocean, December 27, 1923.
(Plotted by F. A. Young.)

Chart VIII. Weather Map of North Atlantic Ocean, December 27, 1923.
(Plotted by F. A. Young.)

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
• rain, ▲ hail or sleet, ✳ snow.
≡ fog.
Pointed arrows indicate land stations.

Arctic Circle

Tropic of Cancer

Chart IX. Weather Map of North Atlantic Ocean, December 28, 1923.

(Plotted by F. A. Young.)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Tropic of Cancer

Chart X. Weather Map of North Atlantic Ocean, December 29, 1923.

(Plotted by F. A. Young.)

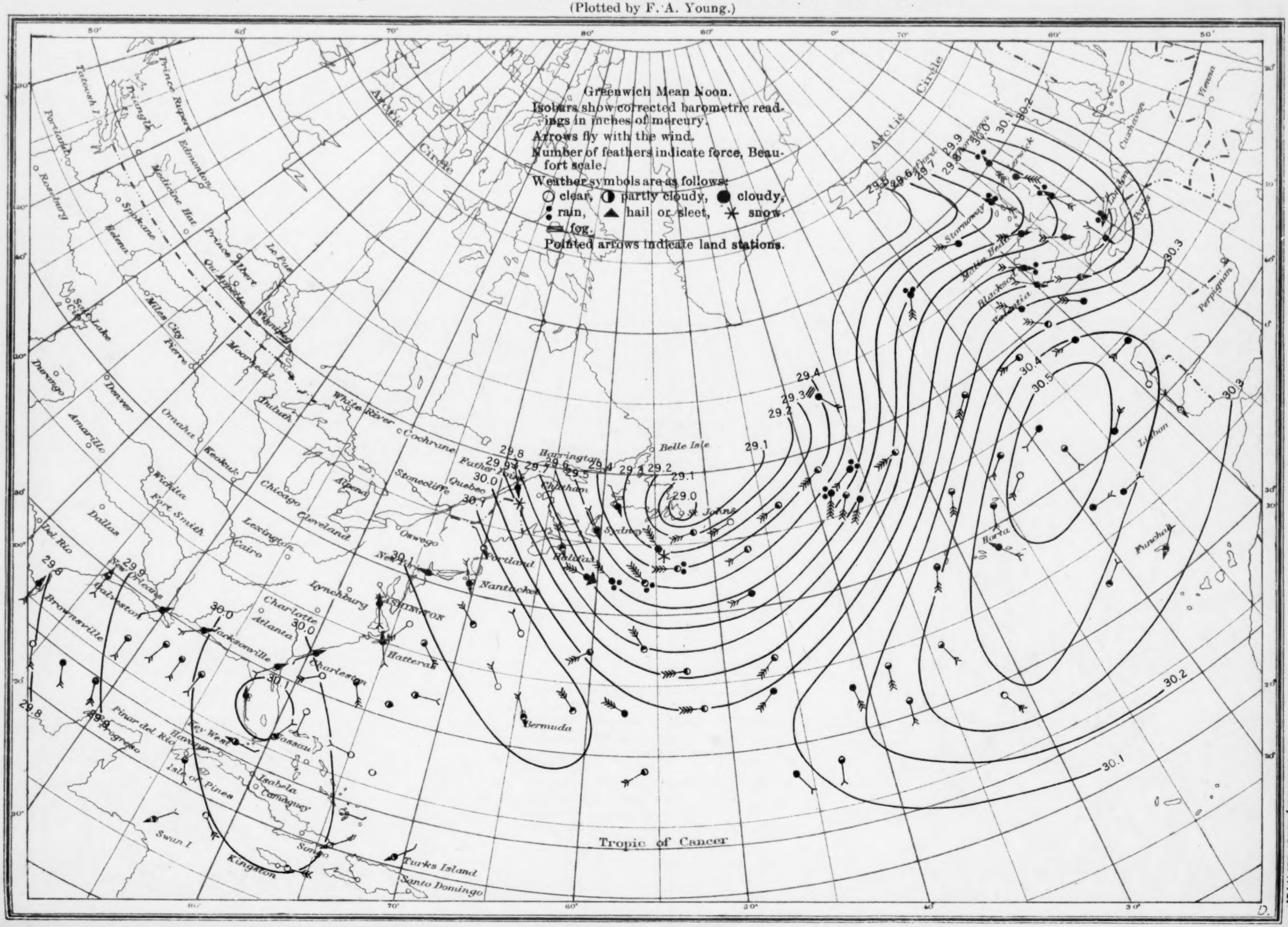
Chart X. Weather Map of North Atlantic Ocean, December 29, 1923.
(Plotted by F. A. Young.)

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
• rain, ▲ hail or sleet, ✳ snow,
≡ fog.
Pointed arrows indicate land stations.

Tropic of Cancer

Chart XI. Weather Map of North Atlantic Ocean, December 30, 1923.

(Plotted by F. A. Young.)



December, 1923. M. W. R.

Chart XII. Weather Map of North Atlantic Ocean, December 31, 1923.

(Plotted by F. A. Young.)

Chart XII. Weather Map of North Atlantic Ocean, December 31, 1923.
(Plotted by F. A. Young.)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

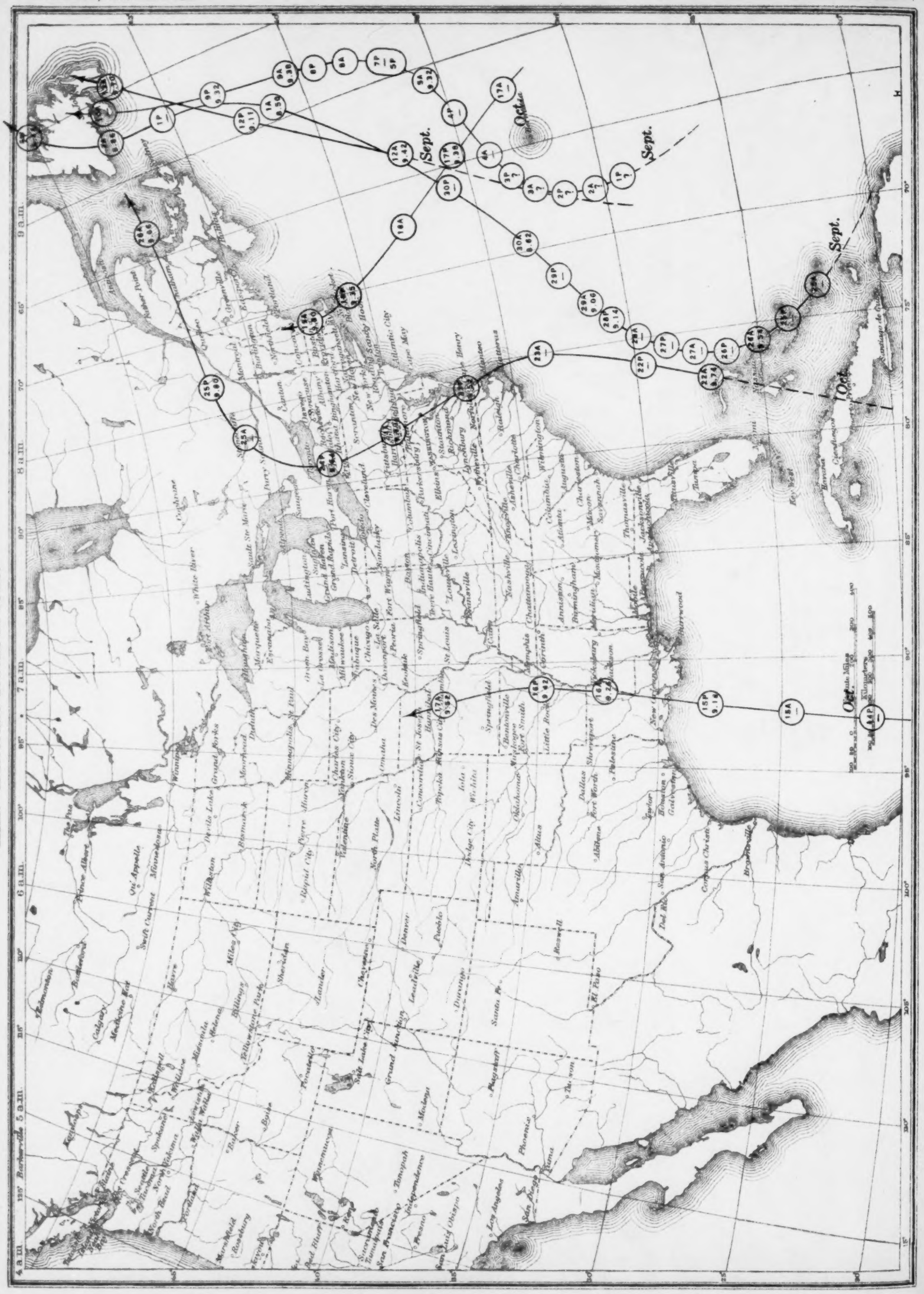
○ clear, ◑ partly cloudy, ● cloudy,
• rain, ▲ hail or sleet, ✳ snow.
≡ fog.

Pointed arrows indicate land stations.

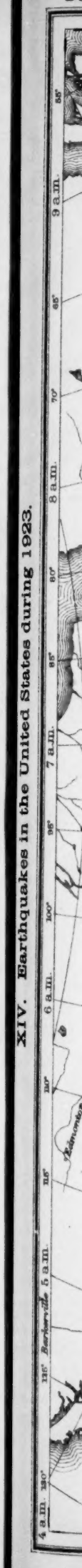
Tropic of Cancer

D

XIII. Hurricane Tracks in 1923.



XIV. Earthquakes in the United States during 1923.



XIV. Earthquakes in the United States during 1923.

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(See inside front cover.)

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In order to make up sets of the 1922 REVIEW for binding, the following issues for 1922 are much needed: January, March, April, and December. Any recipient of the REVIEW who can spare any of these missing numbers will confer a favor by advising the Chief of the Weather Bureau, Washington, D. C., who will gladly send addressed franks by mailing the copies free of charge to the sender.—EDITOR.

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